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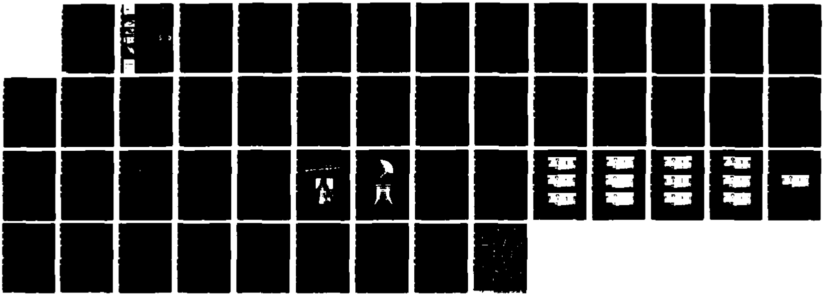

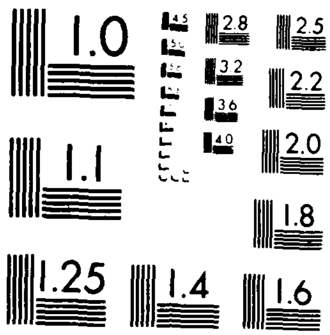
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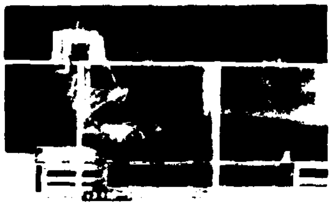

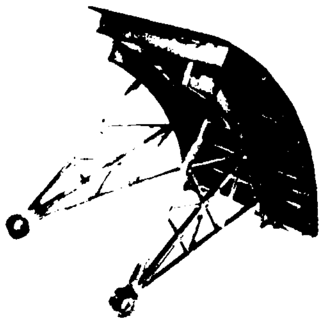

HYDRAULICS LABORATORY

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TECHNICAL REPORT HL-88-

HYDRODYNAMIC FORCES ON TAINTER GATES AND STILLING BASIN OLD RIVER CONTROL AUXILIARY STRUCTURE

Hydraulic Model Investigation

by

B. P. Fletcher, J. L. Grace, Jr.

Hydraulic Laboratory

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Tests were conducted using a 1:50-scale section model to determine the magnitude and frequency of the hydrodynamic loads acting on the tainter gate trunnions and hoist cables, and the stilling basin apron monoliths, baffles, and end sill.

Force measurements at the gate trunnions indicated that the trunnions were subjected to static loadings in an upward and downstream direction. Gate hoist cable loads were occasionally periodic and always in a downward direction.

The location, frequency, and magnitude of the resultant forces acting on the stilling basin apron were determined. Also tests were conducted to determine the forces acting on the baffles and end still. The measured drag forces on the baffle blocks were significantly higher than drag forces computed from drag coefficients. This indicated the need for research or site-specific studies to develop design guidance for determining the individual and collective forces acting on stilling basins.

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19. ABSTRACT (Continued).

Piezometers and electronic pressure cells were used to measure pressure distribution in the stilling basin. Water-surface profiles were obtained along the longitudinal center line of the stilling basin.

A skin plate covering the girders on the downstream side of the tainter gate prevented debris from accumulating on the gate. The skin plate did not alter the hydraulic loads on the tainter gate.

PREFACE

The model investigation was authorized by the Office, Chief of Engineers (OCE), US Army on 13 January 1981 at the request of the US Army Engineer District, New Orleans.

The study was conducted in the Hydraulics Laboratory (HL) of the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, during the period January 1981 to August 1981 under the direction of Mr. H. B. Simmons, former Chief, HL, and under the general supervision of Messrs. J. L. Grace, Jr., former Chief, Hydraulic Structures Division (HSD), and N. R. Oswalt, Chief, Spillways and Channels Branch. Mr. F. A. Herrmann, Jr., Chief, HL. Project engineer for the model was Mr. B. P. Fletcher, HSD, Assisting were Messrs. P. Bhramayana and B. P. Perkins, HSD. This report was prepared by Messrs. Fletcher and Grace.

During the course of the investigation, Messrs. Rodney Resta, Henry G. Reed, Lawrence H. Cave, William Pinner, Loren Heiple, Victor M. Agostinelli, Roland J. Dubuission, Frank Weaver, Robert I. Kaufman, Estes Walker, Larry F. Cook, Henry S. Martin, and Lawrence A. Rabalias of the Lower Mississippi Valley Division; and Frederic M. Chatry, Bob Fairless, Bill Gwyn, Tom Johnson, Tom Hassenboehler, Jim Miles, Cecil Soileau, Tilden Dufrene, Steve Martin, and P. A. Becnel, Jr., of the New Orleans District visited WES to discuss the program of model tests and observe the model in operation.

Commander and Director of WES during the preparation and publication of this report was COL Dwayne G. Lee, CE. Technical Director was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
inches	25.4	millimetres
kips (force)	4448.222	newtons
kips (force) per foot	1.355818	metre kilonewtons
miles (US statute)	1.609344	kilometres

HYDRODYNAMIC FORCES ON TAINTER GATES AND STILLING BASIN
OLD RIVER CONTROL AUXILIARY STRUCTURE

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The Old River Control Auxiliary Structure (Figure 1) is located within the lower limits of the Red River backwater area on the west bank of the Mississippi River about 48 miles* northwest of Baton Rouge, Louisiana, and about 37 miles southwest of Natchez, Mississippi.

2. The approach channel to the structure has a bottom width of 500 ft, an invert elevation of -10.0,** side slopes of 1 on 4 (Figure 2), and a length of approximately 2 miles from its junction with the Mississippi River. The approach training walls to the structure have a top elevation of 72.5 which is 3 ft above the crest of the project flood.

3. The structure is pile founded, constructed of reinforced concrete, and has a gross width of 442 ft between faces of abutment walls. The crest is surmounted by five 14-ft-wide piers that provide bays for six 62-ft-wide tainter gates (Figures 2 and 3). The gates are raised, lowered, and held in position by cables and drum hoists. The weir crest of the structure is set at an elevation of -5.0 to provide sufficient discharge for navigation and water supply needs with minimum stages in the Atchafalaya Basin.

4. The stilling basin (Figure 3) has a length of 210 ft, width of 442 ft, and floor elevation of -20.0. The stilling basin training walls with a top elevation of 55.0 terminate at the end sill. Energy dissipation is provided by two rows of 15-ft-high baffles and a 12-ft-high end sill with a face slope of 1V on 1H.

5. The outlet channel is lined with riprap and has a trapezoidal cross

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

** All elevations (el) and stages cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

section with an inverted elevation of -10, a bottom width of 475 ft, and side slopes of 1V on 6H (Figure 2).

Purpose of Investigation

6. The model tests were conducted to determine the magnitudes, frequencies, and locations of the resultant hydrodynamic loads acting on the tainter gate's trunnions and hoist cables, and the stilling basin's apron monoliths, baffles, and end sill.

PART II: THE MODEL

Description

7. The section model was constructed to a linear scale of 1:50 and simulated one gate bay of 62 ft width (Figures 3 and 4). A 250-ft-long reach of the approach and exit channels was reproduced. The model sidewalls were constructed of plastic to permit visual observation of subsurface currents. As the study progressed, the simulated width of the stilling basin and exit channel was increased to 162 ft (Figure 2) to maintain water-surface profiles and hydraulic jump action indicated by the 1:50-scale model* of the entire structure.

8. Water used in the operation of the section model was supplied by pumps, and discharges were measured by orifice meters. Water-surface elevations were measured by point gages.

9. The model gate was constructed of galvanized metal to simulate a prototype weight of 905 kips and the proper geometric configuration (Figure 5). The gate was supported by trunnions and a cable on each side of the gate. A spring was attached in each cable to simulate the elastic characteristics of the prototype cable. About 0.003 ft clearance was provided between each side of the gage and the model sidewalls to eliminate friction and excessive damping of forces. The hoist cables and trunnions were instrumented with strain gages to permit simultaneous measurement of the loads in the cables and the vertical and horizontal components of the resultant loads on the trunnions.

10. The stilling basin elements were constructed of machined aluminum and supported in the lateral horizontal plane by Teflon bearings mounted between the side of the stilling basin apron monolith and the model sidewalls to minimize friction (Figure 4). The stilling basin was supported in the vertical and longitudinal horizontal planes by rigid rods extending from the stilling basin to the strain gages (Figure 6). The rods were attached by pin connections at points A, B, and C (Figure 6). The strain gages had a maximum

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* Fletcher, B. P., and Bhramayana, P. "Old River Control Auxiliary Structure: Hydraulic Model Investigation" (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

deflection of about 0.002 in. and were mounted to permit simultaneous measurement of the horizontal and vertical loads. About 0.004 ft clearance was provided between the four sides of the stilling basin to eliminate excessive friction and damping of forces.

Interpretation of Model Results

11. The accepted equations of hydraulic similitude, based on the Froudian criteria, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype. The general relations expressed in terms of the model scale or length ratio L_r are presented in the following tabulation:

Dimension	Ratio	Scale Relation
Length	L_r	1:50
Area	$A_r = L_r^2$	1:2,500
Velocity	$V_r = L_r^{1/2}$	1:7.07
Discharge	$Q_r = L_r^{5/2}$	1:17,678
Time	$T_r = L_r^{1/2}$	1:7.07
Force	$F_r = L_r^3$	1:125,000
Frequency	$F_r = 1/L_r^{1/2}$	1:0.14

12. Measurement of each of the dimensions or variables can be transferred quantitatively from model to prototype by means of the above scale relations.

PART III: TESTS AND RESULTS

System Response

13. Initial tests were conducted to determine the natural frequency and damping characteristics of the model components and instrumentation used to measure the dynamic forces. The natural frequencies of the model components, when submerged, are listed below:

Stilling basin apron monoliths

Type 1 (single monolith)

Vertical plane - 6 Hz

Horizontal plane - 26 Hz

Type 2 (monoliths 1 and 2)

Vertical plane - 24 Hz

Horizontal plane - 24 Hz

Tainter gate

Trunnions (vertical and horizontal planes) 100 Hz

Cables (with springs) - 14 Hz

The natural frequencies of the model components were considered too high to significantly influence either the magnitude or frequency of the hydraulic forces measured in subsequent tests which had a predominate frequency of about 0.2 Hz (prototype) or 1.4 Hz (model). Several tests conducted with and without the model submerged indicated no significant damping of the forces due to the mechanical system or the hydrostatic load.

Data Acquisition

14. The magnitude and frequency of forces acting on the gate trunnions, hoist cables, and stilling basin were simultaneously detected by strain gages and recorded on oscillograph charts. A typical oscillograph record is shown in Figure 7.

Forces Acting on Tainter Gate

15. Forces acting on the tainter gate (Figure 6) were measured for various gate openings and flow conditions. The various flow conditions

investigated are illustrated in Figure 8a-m. Flow conditions shown in Figures 8b and 8d are not anticipated to occur at the prototype structure but were investigated in the model to obtain results for a wide range of flow conditions. The forces detected on the tainter gates are tabulated in Table 1. Forces were consistent in tending to displace the trunnions in an upward and downstream direction as indicated by the force vectors in Figure 6. The trunnions were not subjected to a significant dynamic loading. Therefore, only a maximum trunnion loading condition is shown in Table 1. For example, Test 2 (Table 1) indicates that the left trunnion has an average force of 3,800 kips at an angle of 23 deg with the horizontal and the right trunnion has an average force of 3,700 kips acting at an angle of 26 deg and the hoist cables on each side of the tainter gate are subjected to an average load of 40 kips and a maximum force of 50 kips occurring at a rate of 0.2 Hz (prototype) in a downward direction. The hoist cables on both sides of each tainter gate are subjected to a downward force fluctuating from 30 to 50 kips at the rate of 0.2 Hz.

Forces Acting on Stilling Basin Elements

Type 1 monolith

16. The type 1 monolith consisted of a single slab extending from a point 6 ft downstream of the PI to the end sill and was supported in the model as shown in Figure 6. The resultant vertical and horizontal forces were determined by summing the vertical and then the horizontal loads at points A, B, and C (Figure 6). The location of the resultant force R was determined by summing moments about A (Figure 6) and solving for X .

$$X = \left[\frac{R_V \ (22)/\mathrm{TAN}\theta + 180 \ (B_V + C_V)}{R_V} \right] + 20$$

Resultant forces acting on the stilling basin are tabulated in Table 2. Flow conditions for Tests 1-18 are identical to those investigated in the tainter gate tests (Table 1). The underside of the stilling basin apron was subjected to a uniform hydrostatic load equivalent to the tailwater elevation. In most tests, due to the depressed water-surface profile of the hydraulic jump, the resultant stilling basin force was in an upward direction. However, some tests were conducted with flow over the end sill near critical depth. This resulted in a higher water-surface elevation inside the stilling basin than the water surface downstream from the stilling basin, and the resultant force was in a downward direction. It should be noted that some values of X, tabulated in Table 2, denote the hydraulic resultant acting outside the stilling basin. The composite resultant would always act within the stilling basin due to the inclusion of the submerged stilling basin weight and sliding resistance. Stilling basin tests indicated that for all flow conditions the stilling basin was subjected to a significant dynamic force that occurred at about 0.2 Hz (prototype). For example, Test 2 (Table 2) indicates that an average shear force of 11.6 kips and a maximum shear force of 15.0 kips is acting on the stilling basin. The stilling basin is subjected to a minimum and maximum shear force of 8.2 to 15 kips at the rate of 0.2 Hz (see Figure 7).

17. Tests 20-26 were conducted with various elements in the basin removed as indicated by the sketches in Table 2. Results of Tests 20-26 provide limited guidance for estimating the hydraulic forces generated by various basin elements. The guidance is limited due to the change in the hydraulic jump after the baffles and/or end sill are removed. Efforts to keep from altering the jump were successful as described in paragraph 20.

Type 2 monoliths

18. Following tests of the type 1 monolith, New Orleans District engineers decided that the stilling basin apron would be composed of two monoliths due to the length of the apron involved. The model was revised to simulate two monoliths and permit simultaneous measurement of the forces acting on the two independent monoliths (Figure 9). The model facility was also modified by widening the flume downstream from the downstream end of the piers from a width of 62 ft to a width of 162 ft to permit simulation of low tailwater elevations and flow expansion that occurs with single gate operation. Simulation of multiple gate operation required the capability of reducing the flume width to 62 ft by use of a removable divider wall (Figure 2). Details of the mounting system and notations relative to the resultant forces are shown in Figure 9. The procedure for data analysis is similar to that described in paragraph 16.

19. Resultant forces acting on each monolith are tabulated in Table 3. The location of the resultant force, R_1 (monolith 1) was determined by

summing moments about A and solving for X_1 (Figure 9).

$$X_1 = \left[\frac{R_v\ (23)/\mathrm{TAN}\Theta + 55\ (B_v + C_v)}{R_v} \right] + 12.5$$

The location of the resultant force, R_2 (monolith 2) was obtained by summing moments about D and solving for X_2.

$$X_2 = \left[\frac{R_v\ (23)/\mathrm{TAN}\Theta + 55\ (E_v + F_v)}{R_v} \right] + 12.5$$

20. Tests were conducted to measure the individual and collective hydraulic drag and uplift forces acting on the baffles, end sill, and type 2 monoliths. Initially, the end sill was detached but positioned a distance of 0.25 ft (prototype) above the monolith (Figure 10) in order to maintain the hydraulic flow conditions. This permitted measurement of the collective drag and uplift forces acting on the second row of baffle piers and the stilling basin apron. The resultant forces acting on monolith 2 with the end sill detached are tabulated in Table 4. The baffles were detached from the apron monoliths and supported at a distance of 0.25 ft above the monoliths (Figure 11). This enabled measurement of the drag and uplift forces acting on each apron monolith without the influence of forces that are imposed on the baffles. Forces acting on monoliths 1 and 2 with the baffles detached are tabulated in Table 5. The drag and uplift forces due to the end sill can be obtained by subtracting values obtained with the end sill detached (Table 4) from values obtained with the end sill attached (Table 3). The drag and uplift forces due to the first row of baffles (monolith 1) can be obtained by subtracting values in Table 5 from values obtained with the baffles and end sill attached (Table 3). The drag and uplift forces due to the second row of baffles (monolith 2) can be obtained by subtracting values in Table 5 from values in Table 3. The drag and uplift forces acting on the apron of monolith 1 are tabulated in Table 5. The drag and uplift forces due to the apron of monolith 2 can be obtained by subtracting the sum of the respective values for the second row of baffles and end sill from the values in Table 3. The individual and collective drag and uplift forces acting on the baffles, end sill, and the type 2 monolith aprons are tabulated in Table 6.

21. Piezometer and electronic pressure cells were located level with the surface of the stilling basin and in the baffles and end sill as shown in Figure 12 to measure the magnitudes of the average and instantaneous pressure fluctuations. Values obtained for various flow conditions are tabulated in Table 7.

Water-Surface Profiles

22. Water-surface profiles obtained for various flow conditions are shown in Figure 13 with basic data defining the profiles also included.

23. A comparison of the water-surface profiles (Figure 13) with the pressures detected by the piezometers (Table 7) indicates, at some locations, a considerable difference in pressure and equivalent depth for identical flow conditions. The water-surface profile indicates the depth of water relative to the surface of the stilling basin whereas the piezometers indicate a point pressure relative to the surface of the stilling basin that is significantly affected by air entrainment and localized turbulence and flow direction. Depending on its location in the stilling basin, a piezometer could indicate an average pressure higher or lower than the equivalent depth of water over the sensor.

Debris on Tainter Gate

24. Although only limited accumulations of debris are expected, tests to evaluate debris passage during gate flows were conducted with debris that varied in size from 12 ft long and 0.75 ft in diameter to 50 ft long and 5 ft in diameter. Tests indicated that debris would pass underneath the gate and remain in the back roller on the downstream side of the gate. The debris did not impart severe loads to the tainter gate but tended to collect on the downstream side of the gate in the girders and strut arms (Figure 14, type 1 gate). The debris was considered a potential problem in raising and lowering the gate. The problem was alleviated by covering the strut arms and girders with a skin plate which prevented the accumulation of debris. A skin plate was also added immediately downstream from the gate lip (Figure 14, type 2 gate) to prevent accumulation of debris that might prevent proper closing of the gate.

25. The addition of the skin plates did not affect the hydraulic forces on the tainter gate.

PART IV: SUMMARY AND DISCUSSION OF RESULTS

26. Results of tests conducted with the stilling basin apron monoliths and tainter gate immersed in water indicated that the natural frequency of the model was too high to influence the results of the tests and there was no discernible damping of the forces due to the mechanical system.

27. Force measurements at the gate trunnions indicated that the trunnions were subjected to static loadings that tended to displace the trunnions in an upward and downward direction.

28. The model gate hoist cables were designed to simulate the proposed prototype cable characteristics. Hoist cable hydraulic loads were always in a downward direction. Some flow conditions produced a periodic loading (in the hoist cables located on each side of the gate) that occurred at an amplitude of 20 kips and a frequency of 0.2 Hz.

29. Tests were conducted to determine the location, direction, and frequency of the resultant forces acting on the stilling basin apron monoliths and to measure the individual and collective hydraulic drag and uplift forces acting on the baffles, end sill, and stilling basin apron monoliths. The upstream independent monolith was surmounted by a row of baffle blocks and the downstream independent monolith was surmounted by a row of baffle blocks and end sill. The individual drag and uplift forces acting on the aprons, baffles, and end sill were determined by conducting tests with the baffles and then the end sill detached but positioned a distance of 0.25 ft (prototype) from the apron to preserve the characteristics of the hydraulic jump.

30. The measured drag forces on the baffle blocks was significantly higher than drag forces computed from the drag coefficient in EM 1110-2-1603*. This indicates the need for research or site-specific studies to develop design guidance for determining the individual and collective forces acting on stilling basins.

31. Piezometers and electronic pressure cells were used to measure pressure distribution in the stilling basin. Water-surface profiles were obtained along the longitudinal center line of the stilling basin.

32. Tests conducted to evaluate debris passage through the tainter

* Headquarters, Department of the Army. 1965 (Mar). "Hydraulic Design of Spillways," Engineer Manual EM 1110-2-1603, Washington, DC.

gates indicated a tendency for debris to accumulate on the downstream side of the gate. Debris accumulation was eliminated by covering the girders on the downstream side of the gate with a skin plate. The skin plate did not alter the hydraulic loads on the tainter gate.

Table 1

Magnitude, Frequency, and Direction of Resultant Average and Maximum Hydraulic Forces Acting on Tainter Gate

Test No.	Unit Discharge cfs/ft	Gate Opening ft	Headwater ft	Tailwater ft	ΔH ft	Maximum Force Acting on Each Trunnion,* kips: Vertical T_{1V}	Horizontal T_{1H}	Vertical T_{2V}	Horizontal T_{2H}	Resultant T_1	Resultant T_2	Resultant Direction deg α_1	α_2	Force on Each Cable,* kips: Average G_1	Average G_2	Minimum G_1	Minimum G_2	Frequency on Each Cable cps G_1	G_2
1	270	7.5	36	8	28	800↑	1,350→	800↑	1,250→	1,600	1,500	31	33	25↓	25↓	25↓	25↓	--	--
2	310	7.5	69	26	43	1,500↑	3,500→	1,600↑	3,300→	3,800	3,700	23	26	40↓	40↓	50↓	50↓	0.2	0.2
3	270	10	23	6	17	180↑	375→	180↑	375→	420	420	26	26	10↓	10↓	10↓	10↓	--	--
4	400	10	46	15	31	800↑	1,450→	800↑	1,450→	1,660	1,660	29	29	25↓	25↓	25↓	25↓	--	--
5	270	10	65	47	18	630↑	1,700→	560↑	1,500→	1,800	1,600	20	20	5↓	5↓	5↓	5↓	--	--
6	470	11	69	21	48	900↑	4,000→	900↑	4,000→	4,100	4,100	13	13	40↓	40↓	55↓	55↓	0.2	0.2
7	430	11	69	35	34	880↑	3,200→	900↑	3,000→	3,300	3,100	16	17	40↓	40↓	50↓	50↓	0.2	0.2
8	280	11	69	53	16	500↑	2,000→	500↑	2,000→	2,100	2,100	14	14	5↓	5↓	5↓	5↓	--	--
9	240	15	18	13	5	40↑	80→	40↑	80→	90	90	27	27	5↓	5↓	5↓	5↓	--	--
10	400	15	52	35	17	500↑	1,250→	450↑	1,130→	1,350	1,220	22	22	10↓	10↓	10↓	10↓	--	--
11	590	35	41	35	6	30↑	130→	30↑	130→	130	130	13	13	5↓	5↓	5↓	5↓	--	--
12	950	35	55	39	16	100↑	680→	110↑	650→	690	660	8	10	10↓	10↓	15↓	15↓	0.2	0.2
13	930	35	69	53	16	130↑	1,250→	130↑	1,130→	1,260	1,140	6	7	5↓	5↓	15↓	15↓	0.2	0.2
14	177	6.4	69	46	23	800↑	2,200→	800↑	2,200→	2,340	2,340	20	20	10↓	10↓	10↓	10↓	--	--
15	392	12.4	52	38	14	380↑	1,000→	380↑	1,000→	1,070	1,070	21	21	10↓	10↓	10↓	10↓	--	--
16	285	16.7	69	62	7	250↑	750→	250↑	750→	790	790	18	18	10↓	10↓	10↓	10↓	--	--
17	21	1.0	69	45	24	900↑	2,500→	900↑	2,500→	2,660	2,660	20	20	5↓	5↓	5↓	5↓	--	--
18	1,005	39.0	52	39	13	40↑	330→	40↑	330→	330	330	7	7	10↓	10↓	15↓	15↓	0.2	0.2

Note: No significant periodic forces acting on trunnions; therefore, maximum force is a static (average) condition. Tabulated values do not include weight of tainter gate. Direction of horizontal and vertical forces indicated by arrows (→). All values are listed in prototype equivalents.

* See Figure 7.

Table 2

Type 1 Monolith Design; Magnitude, Frequency, Location, and Direction of Resultant Average and Maximum Hydraulic Forces Acting on Stilling Basin per Foot of Basin Width

						Average Force Per Foot of Stilling Basin Width					Maximum Force Per Foot of Stilling Basin Width							
Test No.	Unit Discharge cfs/ft	Gate Opening ft	Headwater ft	Tailwater ft	ΔH ft	Vertical (R_V) kip	Horizontal (R_H) kip	Resultant (R) kip	Resultant Location (X) ft	Resultant Angle C deg	Vertical (R_V) kip	Horizontal (R_H) kip	Resultant (R) kip	Resultant Location (X) ft	Resultant Angle C deg	Frequency (f) cps	Flow Conditions	Design
1	270	7.5	36	8	28	0.16↓	9.0→	9.0	6,135	1.0	6.0↑	13.6→	14.9	155.0	23.8	0.2	Submerged controlled flow	
2	310	7.5	69	26	43	19.8↑	11.6→	23.0	43	59.6	25.0↑	15.0→	29.0	60.0	59.0		Submerged controlled flow	
3	270	10	23	6	17	9.5↓	5.5→	11.0	144	59.9	5.6↓	8.0→	9.8	165.2	35.0		Free controlled flow	
4	400	10	46	15	31	1.3↑	12.1→	12.2	1,055	6.1	9.3↑	17.8→	20.0	88.0	27.6		Submerged controlled flow	
5	270	10	65	47	18	10.3↑	3.2→	10.8	113.9	72.7	13.6↑	5.3→	14.6	115.9	68.7			
6	470	11	[illegible]	21	48	22.6↑	12.7→	25.8	42.5	60.7	33.9↑	16.3→	37.6	75.0	64.3			
7	430	11	69	35	34	22.3↑	12.6→	25.6	60.5	60.5	27.9↑	16.6→	32.5	60.8	59.3			
8	280	11	69	53	16	7.7↑	6.3→	10.0	118.5	50.7	10.6↑	8.6→	13.7	123.6	51.0			
9	240	15	18	13	5	4.4↑	3.2→	5.4	49.1	54.0	2.2↓	5.5→	5.9	-38.1	21.8			
10	400	15	52	35	17	13.7↑	6.9→	15.4	69.7	63.3	19.4↑	9.8→	21.7	72.0	63.2			
11	590	35	41	35	6	5.2↑	8.0→	9.5	28.6	33.0	1.4↓	13.4→	13.5	-112.7	6.0			
12	950	35	55	39	16	2.9↑	14.4→	14.7	202.7	11.4	11.0↑	20.0→	22.8	150.6	28.8			
13	930	35	69	53	16	12.9↑	10.6→	16.7	117.3	50.6	20.2↑	15.8→	25.7	111	52.0			
14	177	6.4	69	46	23	7.0↑	4.0→	8.1	132	60.3	9.7↑	6.1→	11.5	126	57.8			
15	392	12.4	52	38	14	10.0↑	3.7→	10.7	101	69.7	12.9↑	4.9→	13.8	108	58.4			
16	285	16.7	69	62	7	5.3↑	3.9→	6.6	135	53.7	8.1↑	5.7→	9.9	139	54.9			
17	21	1.0	69	46	23	0	0	0	--	--	0.3↑	0.3→	0.42	105	45.0			
18	1,005	39.0	52	39	13	10.8↑	14.0→	17.7	126	37.7	15.7↑	16.9→	23.1	130	42.9			
19	1,370	Fully	52	30	22	20.3↓	18.3→	27.3	66.3	48.0	13.6↓	22.3→	26.1	38	31.4		Submerged uncontrolled flow	
20	310	7.5	69	26	43	24.8↑	9.0→	26.4	45.9	70.0	31.6↑	11.7→	35.9	66.1	69.7		Submerged controlled flow	
21	400	15	52	35	17	18.5↑	6.6→	19.6	63.9	70.0	24.4↑	8.9→	26.0	50.2	70.0			
22	310	7.5	69	26	43	31.1↑	7.4→	32.0	48.4	76.6	38.7↑	10.4→	40.1	55.1	75.0			
23	400	15	52	35	17	19.8↑	5.2→	0.5	50.2	75.3	26.5↑	7.9→	27.7	56.3	73.4			
24	310	7.5	69	26	43	31.6↑	0	31.6	73.3	0	36.5↑	1.2→	36.5	78.0	88.1			
25	400	15	52	35	17	21.8↑	0	21.8	75.1	0	28.5↑	1.2→	28.5	68.0	87.6			
26	1,370	Fully	52	30	22	11.9↑	13.2→	17.8	132	42.0	16.8↑	16.1→	23.3	125	46.2		Submerged uncontrolled flow	

Note: Tabulated values do not include weight of stilling basin. Direction of horizontal and vertical forces indicated by arrows (→). All values are listed in prototype equivalents. Underside of stilling basin subjected to a uniform hydrostatic load equivalent to 100 percent tailwater.

Table 3

Type 2 Monolith Design; Magnitude, Frequency, Location, and Direction of Resultant Average and Maximum Hydraulic Forces Acting on Stilling Basin per Foot of Basin Width

						Average Force Per Foot of Stilling Basin Width					Maximum Force Per Foot of Stilling Basin Width							
Test No.	Unit Discharge cfs/ft	Gate Opening ft	Headwater ft	Tailwater ft	ΔH ft	Vertical (R_v) kip	Horizontal (R_H) kip	Resultant (R) kip	Resultant Location (X) ft	Resultant Angle Θ deg	Vertical (R_v) kip	Horizontal (R_H) kip	Resultant (R) kip	Resultant Location (X) ft	Resultant Angle Θ deg	Frequency (f) cps	Flow Conditions	Design
										Monolith Number 1								
[illegible]	1,370	Fully	52.0	24.3	27.7	4.0↓	11.1→	11.8	22.5	19.8	-0-	14.0→	14.0	∞	0	0.2	Free uncontrolled flow	
28	280	11	69.0	53.0	16.0	4.5↑	4.2→	6.2	63.3	47.0	7.1↑	5.8→	10.1	54.0	51.4	0.2	Submerged controlled flow	
29	950	35	55.0	39.0	16.0	0	7.8→	7.8	∞	0	5.5↑	11.0→	11.7	82.0	26.6	0.2	Submerged controlled flow	
30	177	6.4	69.1	45.1	24.0	4.6↑	3.4→	5.7	45.0	53.5	6.0↑	5.0→	7.8	76.5	50.2	0.2	Submerged controlled flow	
31	400	15	52.0	35.0	17.0	8.4↑	4.7→	9.6	45.6	60.8	13.9↑	6.5→	15.3	47.0	64.9	0.2	Submerged controlled flow	
										Monolith Number 2								
27	1,370	Fully	52.0	24.3	27.7	10.3↑	10.6→	14.8	36.5	44.2	15.2↑	14.5→	21.0	45.2	49.4	0.2	Free uncontrolled flow	
28	280	11	69.0	53.0	16.0	2.9↑	1.8→	3.4	31.0	58.2	4.2↑	3.7→	5.6	53.7	48.6	0.2	Submerged controlled flow	
29	950	35	55.0	39.0	16.0	1.9↑	4.4→	4.8	73	23.4	4.7↑	6.5→	8.0	72.0	35.9	0.2	Submerged controlled flow	
30	177	6.4	69.1	45.1	24.0	1.8↑	0.5→	1.9	23.8	74.5	3.4↑	1.4→	3.7	31.4	67.6	0.2	Submerged controlled flow	
31	400	15	52.0	35.0	17.0	2.7↑	1.8→	3.2	44.1	56.3	4.9↑	3.4→	6.0	55.0	55.2	0.2	Submerged controlled flow	

Note: Tabulated values do not include weight of stilling basin. Direction of horizontal and vertical forces indicated by arrows (→). All values are listed in prototype equivalents. Underside of stilling basin subjected to a uniform hydrostatic load equivalent to 100 percent tailwater.

Table 4

Type 2 Monolith Design; End Sill Detached From Monolith Number 2; Magnitude, Frequency, Location, and Direction of Resultant Average and Maximum Hydraulic Forces Acting on Stilling Basin per Foot of Basin Width, Monolith Number 2

Test No.	Unit Discharge cfs/ft	Gate Opening ft	Headwater ft	Tailwater ft	Δh ft	Average Force Per Foot of Stilling Basin Width: Vertical (R_V) kip	Horizontal (R_H) kip	Resultant (R) kip	Resultant Location (X) ft	Resultant Angle Θ deg	Maximum Force Per Foot of Stilling Basin Width: Vertical (R_V) kip	Horizontal (R_H) kip	Resultant (R) kip	Resultant Location (X) ft	Resultant Angle Θ deg	Frequency (f) cps	Flow Conditions	Design
32	1,370	Fully	52.0	24.3	27.7	6.0↑	4.4→	7.4	29.0	53.8	7.9↑	8.6→	11.7	37.5	42.6	0.2	Free uncontrolled flow	
33	280	11	69.0	53.0	16.0	2.4↑	0.8→	2.5	20.2	71.5	3.7↑	1.3→	3.9	20.5	70.6	0.2	Submerged controlled flow	"
34	950	35.0	55.0	39.0	16.0	0.0↑	1.8→	1.8	∞	0	1.5↑	2.9→	3.3	56.0	27.4	0.2	Submerged controlled flow	"
35	177	6.4	69.1	45.1	24.0	1.6↑	0.4→	1.7	19.2	76.0	2.2↑	0.9→	2.4	22.0	67.7	0.2	Submerged controlled flow	"
36	400	15	52.0	35.0	17.0	1.3↑	1.0→	1.6	30.2	52.4	2.4↑	1.5→	2.8	26.4	58.0	0.2	Submerged controlled flow	"

Note: Tabulated values do not include weight of stilling basin. Direction of horizontal and vertical forces indicated by arrows (→). All values are listed in prototype equivalents. Underside of stilling basin subjected to a uniform hydrostatic load equivalent to 100 percent tailwater.

Table 5

Type 2 Monolith Design; Each Row of Baffles Detached from Monoliths; Magnitude, Frequency, Location, and Direction of Resultant Average and Maximum Hydraulic Forces Acting on Stilling Basin per Foot of Basin Width

						Average Force Per Foot of Stilling Basin Width					Maximum Force Per Foot of Stilling Basin Width							
Test No.	Unit Dis-charge cfs/ft	Gate Open-ing ft	Head-water ft	Tail-water ft	ΔH ft	Verti-cal (R_v) kip	Horizon-tal (R_H) kip	Resul-tant (R) kip	Resultant Location (X) ft	Resul-tant Angle θ deg	Verti-cal (R_v) kip	Horizon-tal (R_H) kip	Resul-tant (R) kip	Resultant Location (X) ft	Resultant Angle C deg	Frequency (f) cps	Flow Conditions	Design
										Monolith Number 1								
37	1,370	Fully	52.0	24.3	27.7	16.3↓	0	16.3	43.0	90	11.1↓	0.6→	11.1	33.2	86.9	0.2	Free uncontrolled flow	
38	280	11	69.0	53.0	16.0	2.1↑	0	2.1	25.1	90	3.4↑	0.4→	3.4	36.1	83.3	0.2	Submerged controlled flow	"
39	950	35	55.0	39.0	16.0	6.1↓	0	6.1	53.3	90	3.5↓	0.8→	3.6	48.3	77.1	0.2	Submerged controlled flow	"
40	177	6.4	69.1	45.1	24.0	1.6↑	0	1.6	30.5	90	2.8↑	0.5→	2.9	50.0	79.9	0.2	Submerged controlled flow	"
41	400	15	52.0	35.0	17.0	3.1↑	0	3.1	26.8	90	5.3↑	0.5→	5.3	46.5	84.6	0.2	Submerged controlled flow	"
										Monolith Number 2								
37	1,370	Fully	52.0	24.3	27.7	5.5↑	6.4→	8.4	49.0	40.7	10.2↑	7.8→	12.8	60.6	52.6	0.2	Free uncontrolled flow	"
38	280	11	69.0	53.0	16.0	2.3↑	0.3→	2.3	64.0	82.6	3.1↑	0.7→	3.2	74.0	77.3	0.2	Submerged controlled flow	"
39	950	35	55.0	39.0	16.0	1.7↓	2.4→	2.9	67.0	35.3	0.3↑	3.7→	3.7	33.0	4.6	0.2	Submerged controlled flow	"
40	177	6.4	69.1	45.1	24.0	1.4↑	0.2→	1.4	53.0	81.9	2.1↑	0.6→	2.2	62.5	74.0	0.2	Submerged controlled flow	"
41	400	15	52.0	35.0	17.0	0.5↓	0.6→	0.8	69.0	37.6	1.3↑	1.7→	2.1	76.8	37.4	0.2	Submerged controlled flow	"

Note: Tabulated values do not include weight of stilling basin. Direction of horizontal and vertical forces indicated by arrows (→). All values are listed in prototype equivalents. Underside of stilling basin subjected to a uniform hydrostatic load equivalent to 100 percent tailwater.

Table 7

Hydraulic Forces Acting on Individual and Combined Stilling Basin Elements

Type 2 Monolith Design Dynamic Forces

Monolith Number 1

Unit Discharge cfs/ft	Gate Opening ft	Headwater ft	Tailwater ft	Horizontal (R_H) kip	Baffles,* kips Uplift/Baffle Avg	Baffles,* kips Uplift/Baffle Max	Baffles,* kips Drag/Baffle Avg	Baffles,* kips Drag/Baffle Max	Apron,** kips Uplift/ft Avg	Apron,** kips Uplift/ft Max	Apron,** kips Drag/ft Avg	Apron,** kips Drag/ft Max	Baffles and Aprons,** kips Uplift/ft Avg	Baffles and Aprons,** kips Uplift/ft Max	Baffles and Aprons,** kips Drag/ft Avg	Baffles and Aprons,** kips Drag/ft Max
1,370	Fully	52.0	24.3	[illegible]	252↑	266↑	277→	275→	16.[illegible]	12.9↓	0	0.6→	4.0↓	0.0	11.1→	14.0→
280	11	69.0	53.0	16.0	49↑	76↑	86→	111→	2.1↑	3.4↑	0	0.4→	4.5↑	7.1↑	4.2→	5.8→
950	35	55.0	39.0	16.0	125↑	185↑	160→	209→	6.1↓	3.5↓	0	0.8→	0.0↓	5.5↑	7.8→	11.0→
177	6.4	69.1	45.1	24.0	62↑	74↑	70→	9[illegible]→	1.6↑	2.4↑	0	0.5→	4.6↑	6.0↑	3.4→	5.0→
400	15	52.0	35.0	17.0	108↑	176↑	96→	123→	3.1↑	5.3↑	0	0.5→	8.4↑	13.9↑	4.7→	6.5→

Monolith Number 2

Unit Discharge cfs/ft	Gate Opening ft	Headwater ft	Tailwater ft	Horizontal (R_H) kip	Baffles,** kips Uplift/Baffle Avg	Baffles,** kips Uplift/Baffle Max	Baffles,** kips Drag/Baffle Avg	Baffles,** kips Drag/Baffle Max	End Sill,** kips Uplift/ft Avg	End Sill,** kips Uplift/ft Max	End Sill,** kips Drag/ft Avg	End Sill,** kips Drag/ft Max	Apron,** kips Uplift/ft Avg	Apron,** kips Uplift/ft Max	Apron,** kips Drag/ft Avg	Apron,** kips Drag/ft Max	Baffles, End Sill, and Aprons,** kips Uplift/ft Avg	Baffles, End Sill, and Aprons,** kips Uplift/ft Max	Baffles, End Sill, and Aprons,** kips Drag/ft Avg	Baffles, End Sill, and Aprons,** kips Drag/ft Max
1,370	Fully	52.0	24.3	27.7	148↑	154↑	129→	206→	4.3↑	7.3↑	6.2→	7.4→	1.2↑	2.9↑	0.2→	0.4→	10.3↑	15.2↑	10.6→	14.5→
280	11	69.0	53.0	16.0	18↑	34↑	46→	74→	0.5↑	0.5↑	0.5→	1.9→	1.8↑	2.6↑	0.2←	0.6←	2.9↑	4.2↑	1.8→	3.7→
950	35	55.0	39.0	16.0	111↑	135↑	62→	86→	0.4↑	1.7↑	2.6→	3.6→	2.1↓	1.4↓	0.2←	0.1→	1.9↑	4.7↑	4.4→	6.5→
177	6.4	69.1	45.1	24.0	12↑	40↑	9→	25→	0.2↑	0.7↑	0.1→	0.5→	1.2[illegible]	1.4↑	0.1→	0.1→	1.8↑	3.4↑	0.5→	1.4→
400	15	52.0	35.0	17.0	98↑	111↑	37→	52→	1.4↑	2.5↑	0.8→	1.9→	1.2↓	1.2↓	0.2←	0.0	2.7↑	4.9↑	1.8→	3.4→

Note: Tabulated values do not include weight of stilling basin. Direction of horizontal and vertical forces indicated by arrows (→). All values are listed in prototype equivalents. Underside of stilling basin subjected to a uniform hydrostatic load equivalent to 100 percent tailwater. Maximum forces occur at a frequency of 0.2 cycles per second (prototype).

* Forces acting on baffles are tabulated as force per baffle (each baffle is 9.83 ft wide).

** Forces acting on aprons, end sill, combined apron and baffles on apron, baffles, and end sill are tabulated as a unit force per foot of monolith width (monolith and end sill width in model = 61.5 ft).

Table 7

Pressures in Old River Control Auxiliary Structure

Stilling Basin Monoliths (Type 2)

Piezometer		Pressure Per Foot of H_2O				
		Test No. 27 G_0 = Full q = 1,370 cfs/ft H = 52.0 ft h = 24.3 ft	Test No. 28 G_0 = 11 ft q = 280 cfs/ft H = 69.0 ft h = 53.0 ft	Test No. 29 G_0 = 35 ft q = 950 cfs/ft H = 55.0 ft h = 39.0 ft	Test No. 30 G_0 = 6.4 ft q = 177 cfs/ft H = 69.1 ft h = 45.1 ft	Test No. 31 G_0 = 15 ft q = 400 cfs/ft H = 52.0 ft h = 35.0 ft
No.	Elevation					
1	-20.0	35.5	56.0	43.0	45.0	37.0
2		34.0	55.0	43.0	45.0	35.0
3		31.5	54.0	42.0	44.0	34.0
4		29.5	53.0	41.0	44.0	34.0
5**		3.5	3.0	3.0	3.0	3.0
6		28.0	53.0	40.0	45.0	34.0
7		28.6	53.0	41.0	45.0	34.0
8		29.5	53.0	41.0	45.0	34.0
9		*	*	*	*	*
10		*	*	*	*	*
11		31.0	53.0	41.0	45.0	35.0
12		*	*	*	*	*
13		36.0	55.0	45.0	45.0	36.0
14		39.0	56.0	47.0	47.0	38.0
15**		6.5	4.0	4.0	3.0	5.0
16	-7.5	49.0	60.0	54.0	48.0	40.0
17	-12.5	51.0	64.0	55.0	52.0	45.0
18	-17.5	49.5	63.0	53.0	53.0	45.0
19	-20.0	*	*	*	*	*
20		22.0	53.0	39.0	45.0	35.0
21		23.5	53.0	40.0	45.0	35.0
22		25.5	53.0	40.0	45.0	35.0
23		26.0	53.0	40.0	45.0	36.0
24		26.5	54.0	41.0	46.0	36.0
25		27.0	54.0	41.0	46.0	36.0

(Continued)

Note: Piezometer locations are shown in Figure 12. Elevations are in feet.
* Piezometer malfunction.
** Electronic pressure cells - amplitude of maximum pressure fluctuation in feet.

(Sheet 1 of 3)

Table 7 (Continued)

Piezometer No.	Piezometer Elevation	Pressure Per Foot of H_2O Test No. 27, G_0 = Full, q = 1,370 cfs/ft, H = 52.0 ft, h = 24.3 ft	Test No. 28, G_0 = 11 ft, q = 280 cfs/ft, H = 69.0 ft, h = 53.0 ft	Test No. 29, G_0 = 35 ft, q = 950 cfs/ft, H = 55.0 ft, h = 39.0 ft	Test No. 30, G_0 = 6.4 ft, q = 177 cfs/ft, H = 69.1 ft, h = 45.1 ft	Test No. 31, G_0 = 15 ft, q = 400 cfs/ft, H = 52.0 ft, h = 35.0 ft
26	↓	27.0	53.0	41.0	45.0	36.0
27	↓	28.0	53.0	41.0	45.0	37.0
28	↓	28.0	53.0	40.0	46.0	37.0
29	↓	29.0	54.0	40.0	46.0	37.0
30**	↓	3.5	1.5	1.5	1.5	1.5
31	↓	29.0	54.0	41.0	46.0	37.0
32	-8.0	19.0	54.0	38.0	46.0	36.0
33	-20.0	37.5	53.0	45.0	46.0	39.0
34	↓	26.0	51.0	39.0	44.0	33.0
35	↓	16.5	47.0	35.0	41.0	30.0
36	↓	19.0	50.0	36.0	43.0	32.0
37	↓	23.0	51.0	38.0	44.0	33.0
38	↓	26.0	53.0	39.0	45.0	34.0
39	-19.0	26.0	53.0	35.0	48.0	37.0
40	-15.0	25.0	52.0	36.0	46.0	33.0
41	-10.0	25.0	54.0	37.0	46.0	34.0
42	-5.0	25.0	54.0	38.0	45.0	33.0
43	0	24.0	53.0	38.0	45.0	33.0
44	-5.0	23.0	53.0	38.0	45.0	33.0
45	10.0	23.0	53.0	37.0	44.0	34.0
46	15.0	23.0	53.0	38.0	44.0	34.0
47	20.0	*	53.0	38.0	44.0	34.0
48	25.0	*	53.0	38.0	44.0	34.0
49	30.0	*	52.0	38.0	44.0	*
50	35.0	*	52.0	37.0	44.0	*
51	40.0	*	53.0	*	*	*
52	45.0	*	*	*	*	*
53	50.0	*	*	*	*	*
54	-19.0	29.5	54.0	42.0	45.0	35.0

(Continued)

* Piezometer malfunction.
** Electronic pressure cells - amplitude of maximum pressure fluctuation in feet.

(Sheet 2 of 3)

Table 7 (Concluded)

Piezometer		Pressure Per Foot of H_2O				
		Test No. 27 G_0 = Full q = 1,370 cfs/ft H = 52.0 ft h = 24.3 ft	Test No. 28 G_0 = 11 ft q = 280 cfs/ft H = 69.0 ft h = 53.0 ft	Test No. 29 G_0 = 35 ft q = 950 cfs/ft H = 55.0 ft h = 39.0 ft	Test No. 30 G_0 = 6.4 ft q = 177 cfs/ft H = 69.1 ft h = 45.1 ft	Test No. 31 G_0 = 15 ft q = 400 cfs/ft H = 52.0 ft h = 35.0 ft
No.	Elevation					
55	-15.0	27.0	53.0	40.0	45.0	34.0
56	-10.0	25.0	53.0	38.0	45.0	34.0
57	-5.0	24.0	53.0	39.0	45.0	34.0
58	0	24.0	52.0	38.0	45.0	34.0
59	5.0	23.0	52.0	39.0	44.0	34.0
60	10.0	23.0	53.0	38.0	44.0	34.0
61	15.0	*	53.0	38.0	44.0	34.0
62	20.0	*	53.0	38.0	44.0	35.0
63	25.0	*	53.0	38.0	44.0	34.0
64	30.0	*	53.0	38.0	44.0	*
65	35.0	*	53.0	*	*	*
66	40.0	*	*	*	*	*
67	45.0	*	*	*	*	*
68	50.0	*	*	*	*	*

* Piezometer malfunction.

(Sheet 3 of 3)

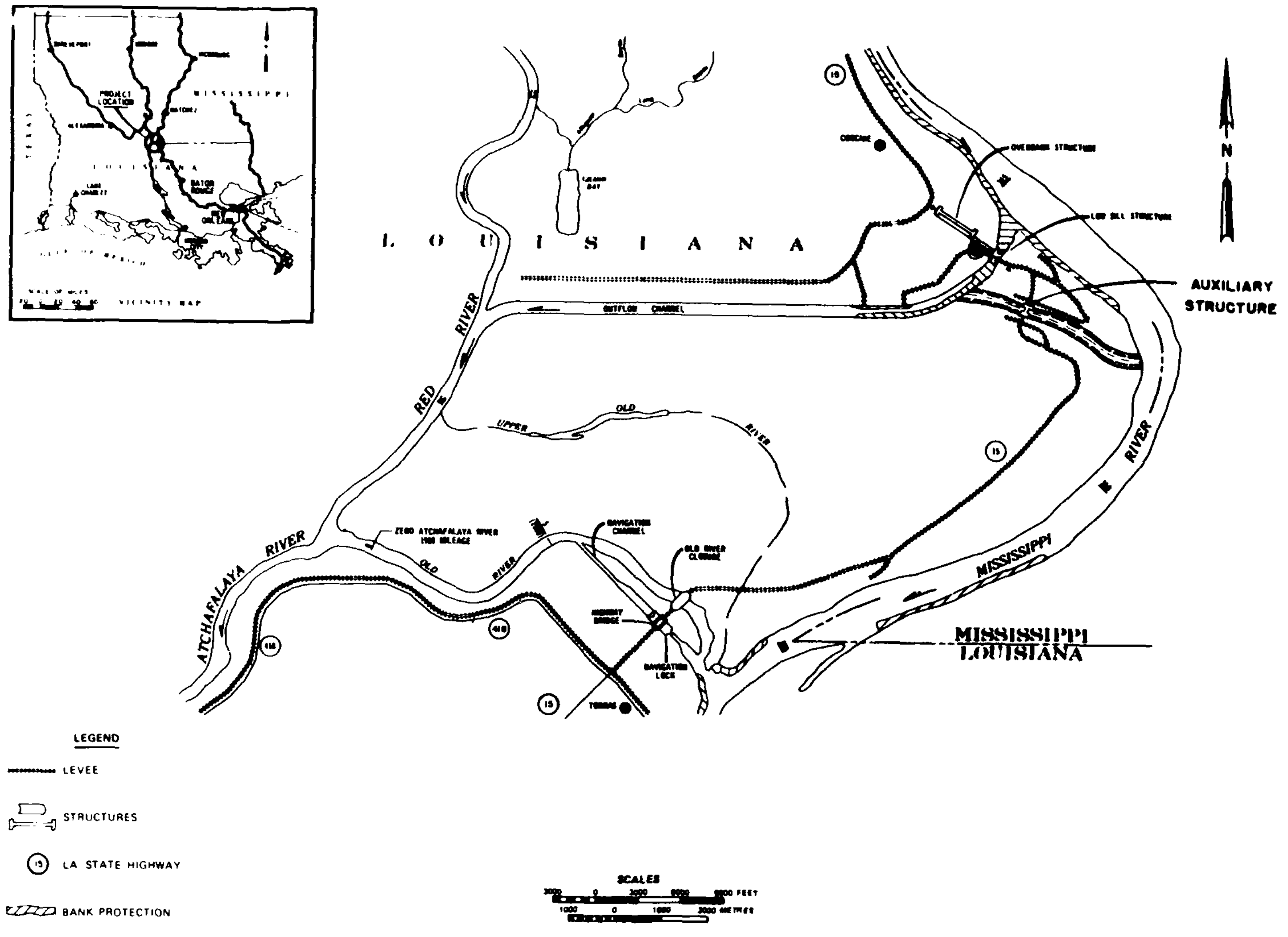


Figure 1. Vicinity map

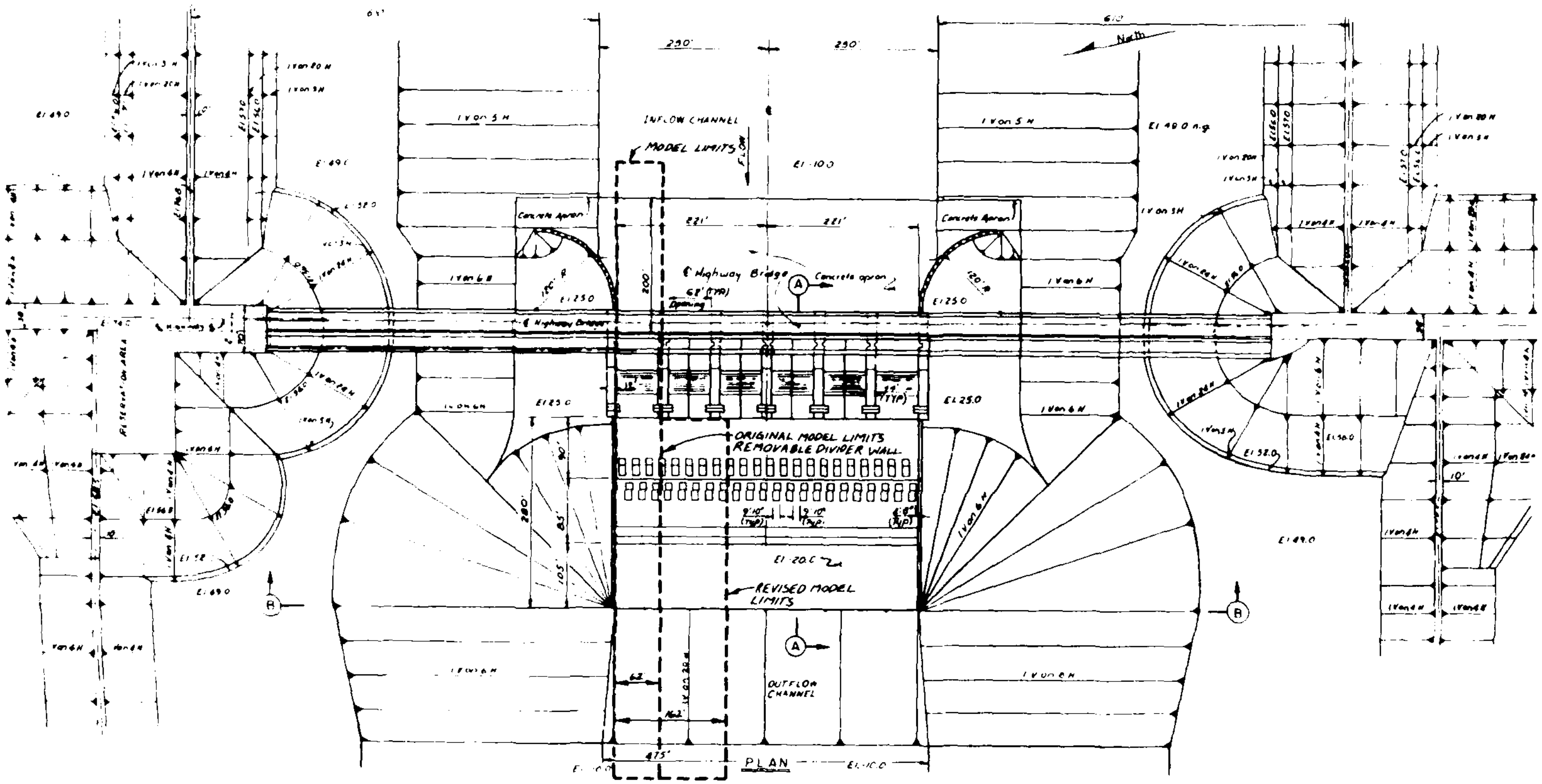


Figure 2. Plan view

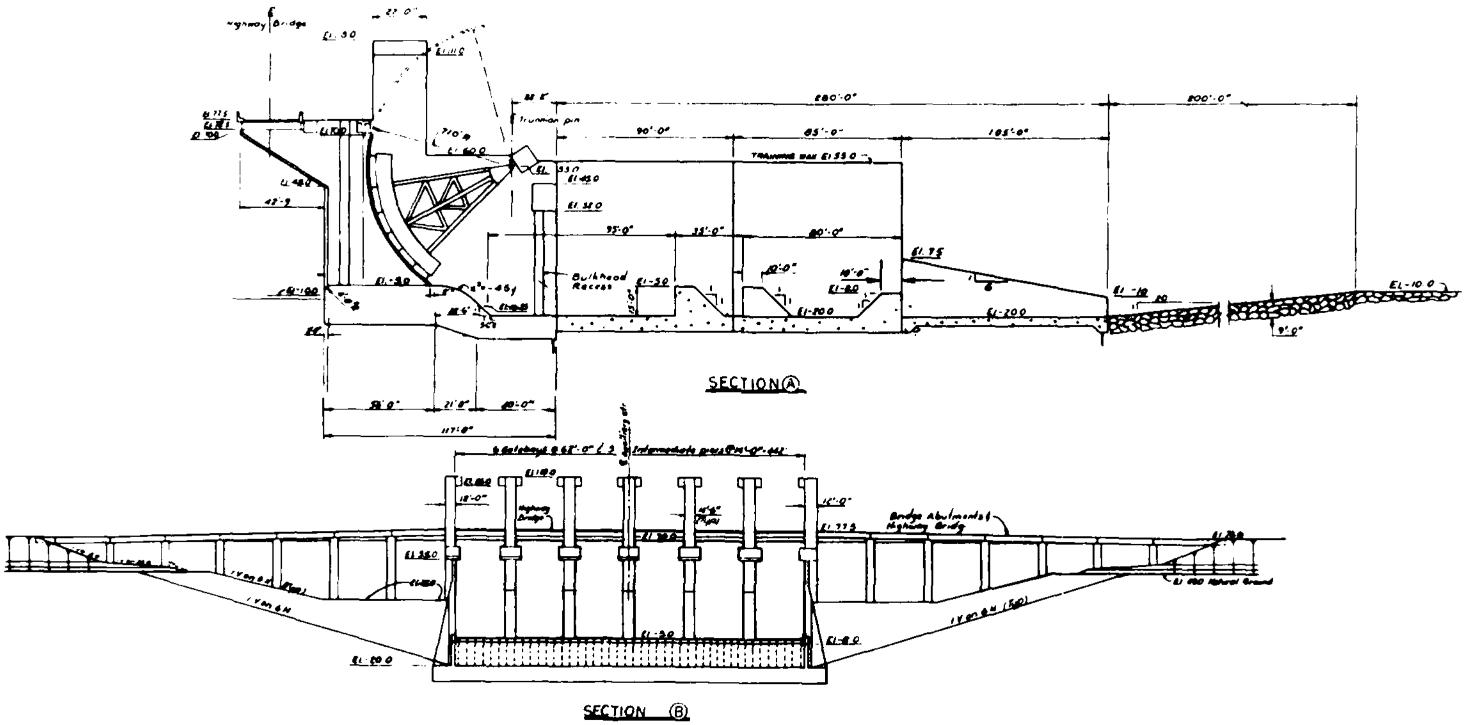
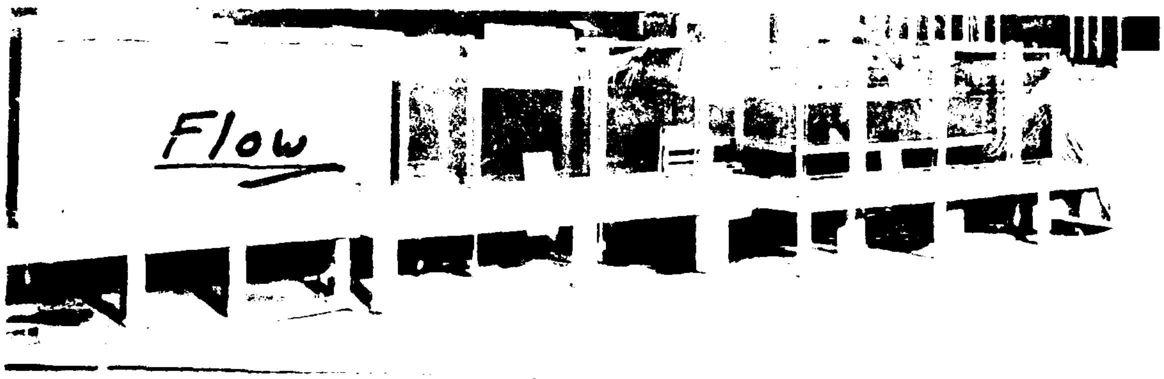


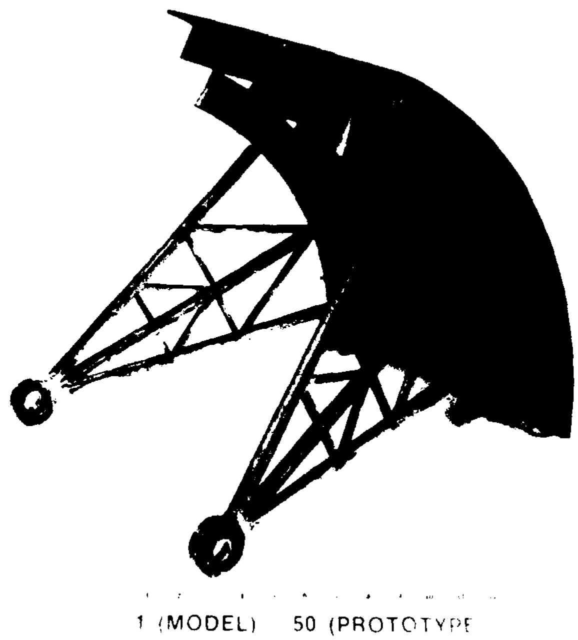
Figure 3. Section model of stilling basin



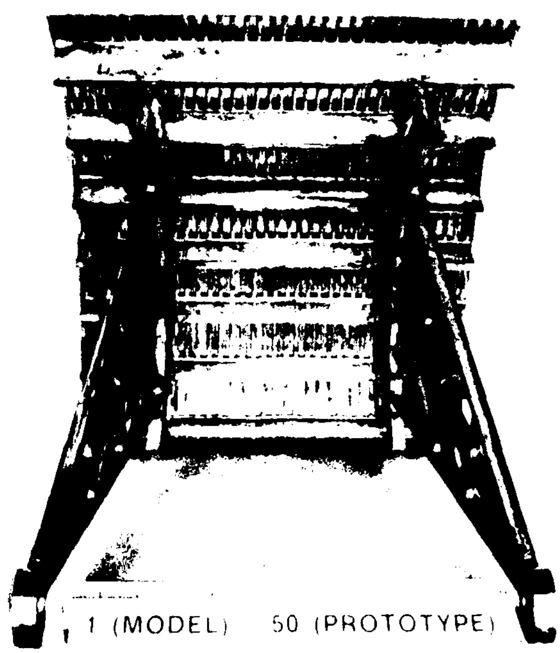
a. General view

b. Viewed from downstream

Figure 4. 1:50-scale section model

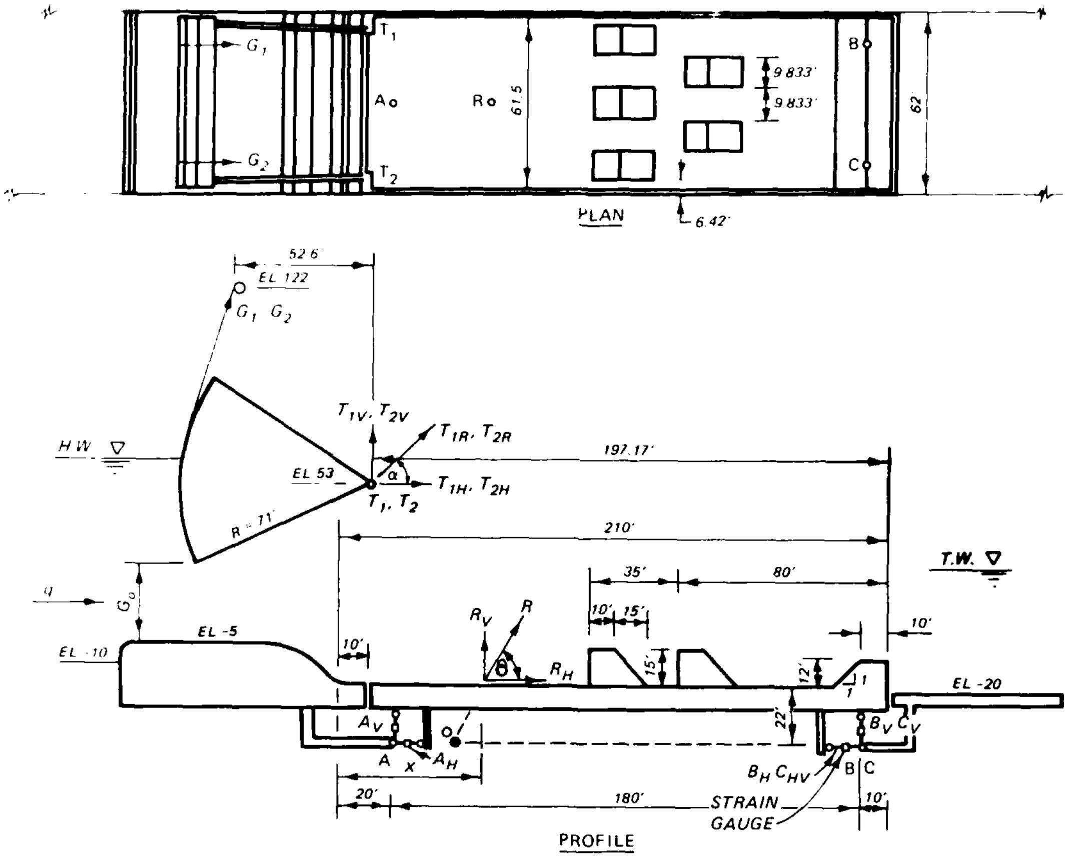


a. Viewed from side



b. Viewed from downstream

Figure 5. Tainter gate



TYPE 1 MONOLITH DESIGN-LOCATION OF GAGES AND FORCE DIRECTION

Figure 6. Stilling basin

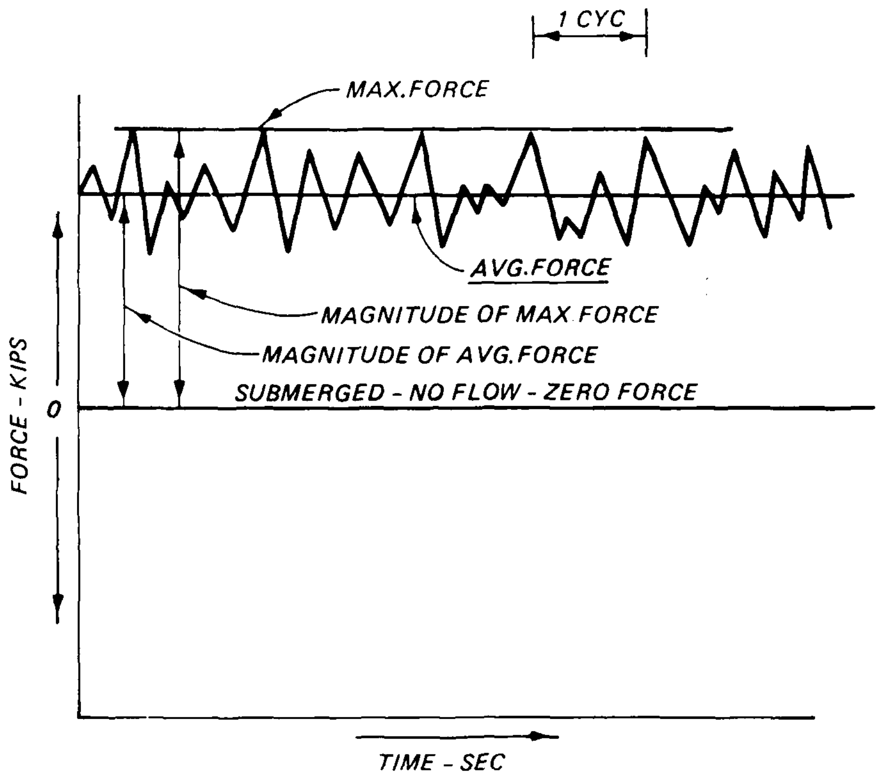
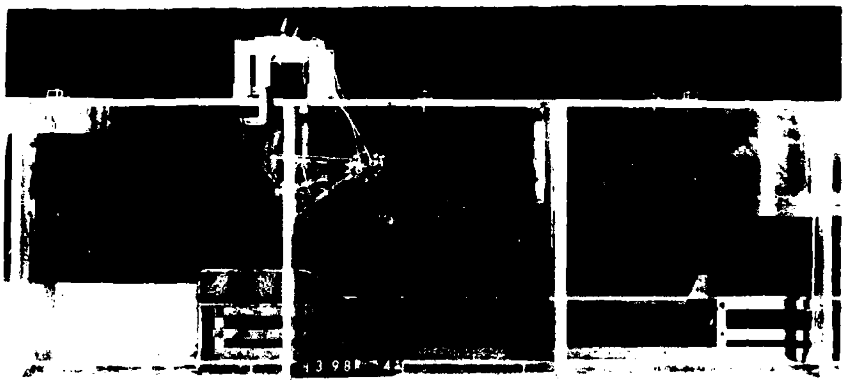
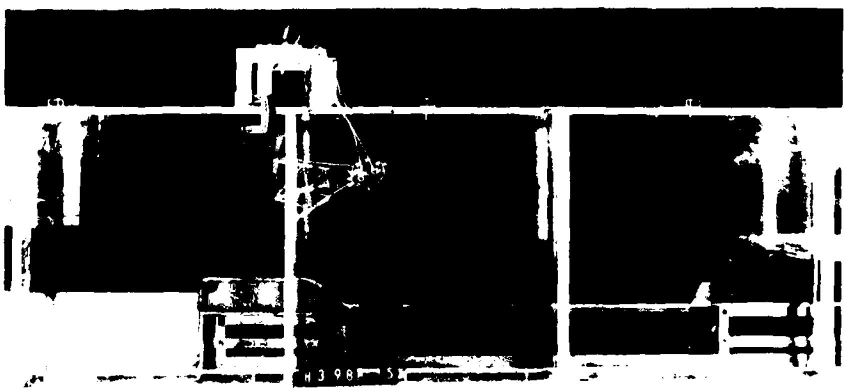


Figure 7. Typical oscillograph record for stilling basin

a. Unit discharge = 270.0 cfs/ft; gate opening = 7.5 ft; pool el = 36.0 ft NGVD; and tailwater el = 8.0 ft NGVD

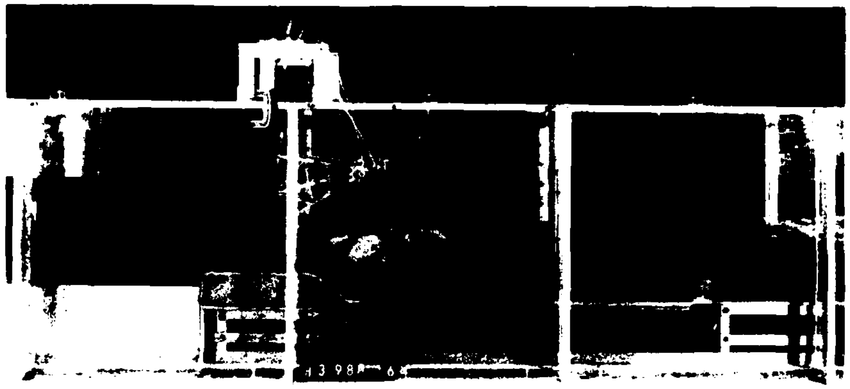


b. Unit discharge = 310.0 cfs/ft; gate opening = 7.5 ft; pool el = 69.1 ft NGVD; and tailwater el = 26.0 ft NGVD

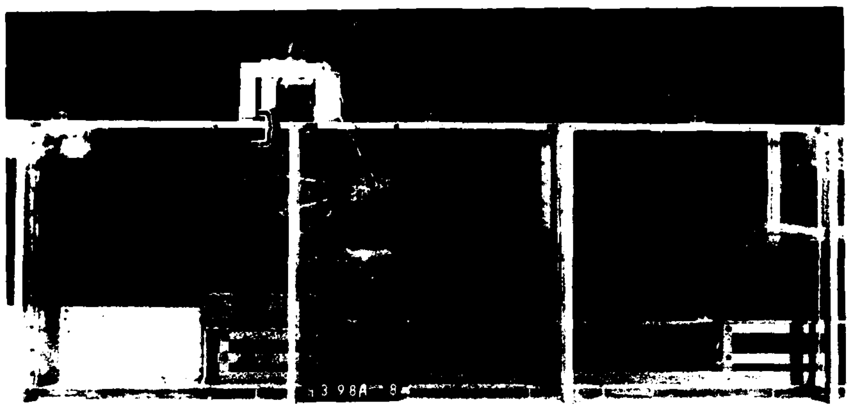


c. Unit discharge = 270.0 cfs/ft; gate opening = 10.0 ft; pool el = 23.0 ft NGVD; and tailwater el = 6.0 ft NGVD

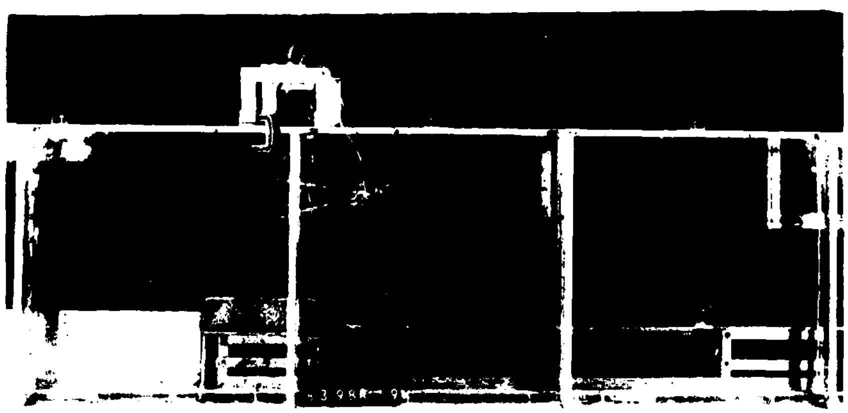
Figure 8. Various flow conditions (sheet 1 of 5)



d. Unit discharge = 400.0 cfs/ft; gate opening = 10.0 ft; pool el = 46.0 ft NGVD; and tailwater el = 15.0 ft NGVD

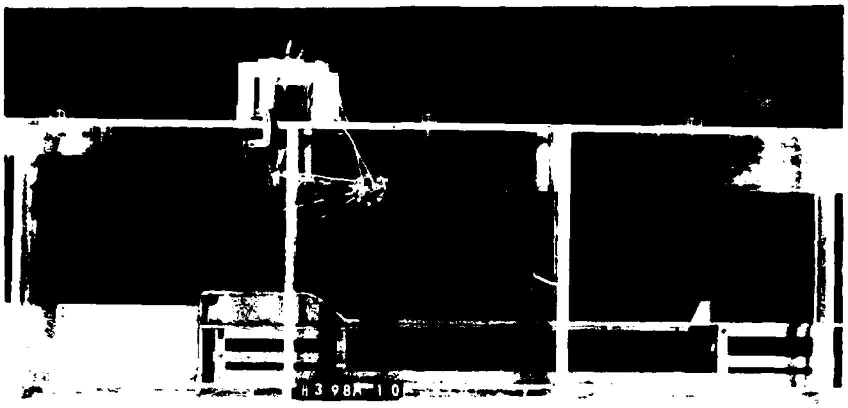


e. Unit discharge = 270.0 cfs/ft; gate opening = 10.0 ft; pool el = 65.0 ft NGVD; and tailwater el = 47.0 ft NGVD

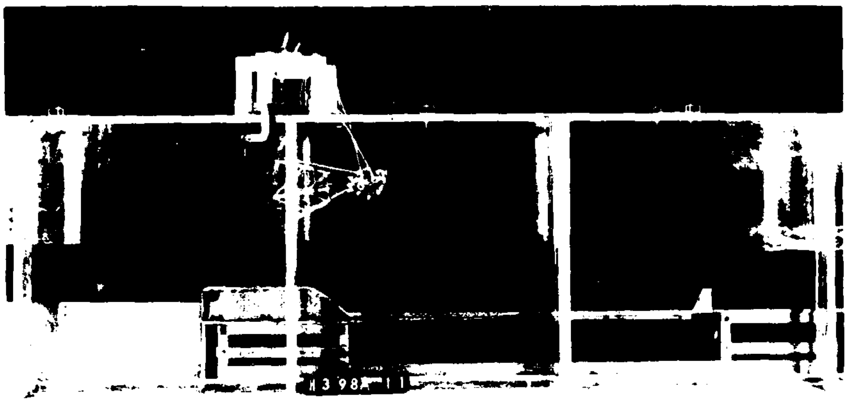


f. Unit discharge = 430.0 cfs/ft; gate opening = 11.0 ft; pool el = 69.1 ft NGVD; and tailwater el = 35.0 ft NGVD

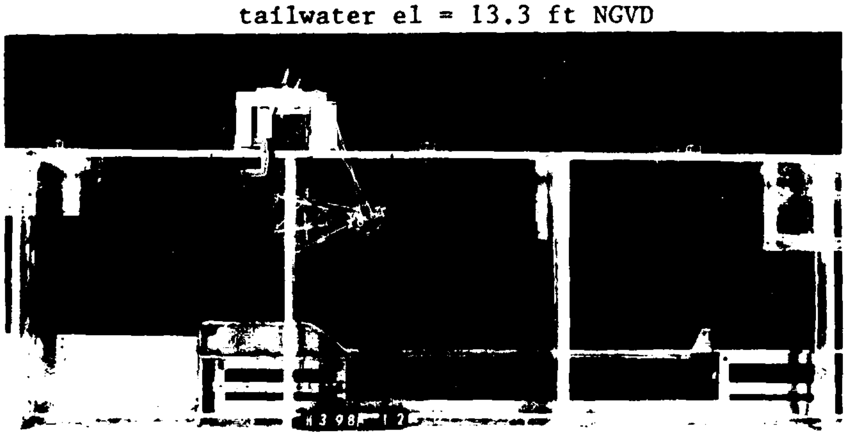
Figure 8. (sheet 2 of 5)



g. Unit discharge = 280.0 cfs/ft; gate opening = 11.0 ft; pool el = 69.1 ft NGVD; and tailwater el = 53.3 ft NGVD

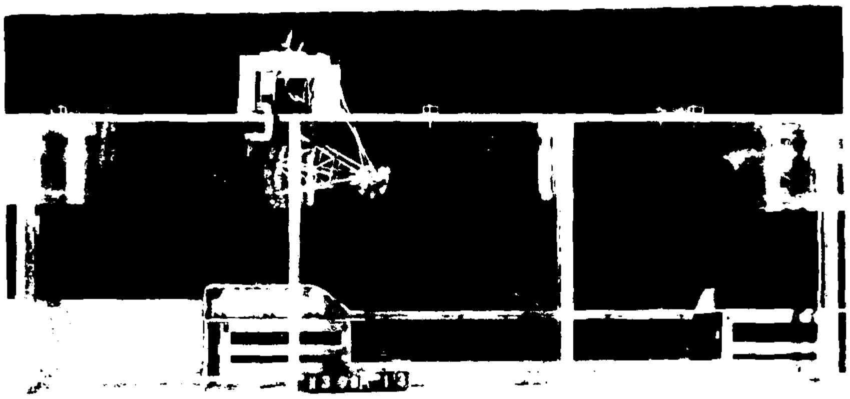


h. Unit discharge = 240.0 cfs/ft; gate opening = 15.0 ft; pool el = 18.0 ft NGVD; and tailwater el = 13.3 ft NGVD

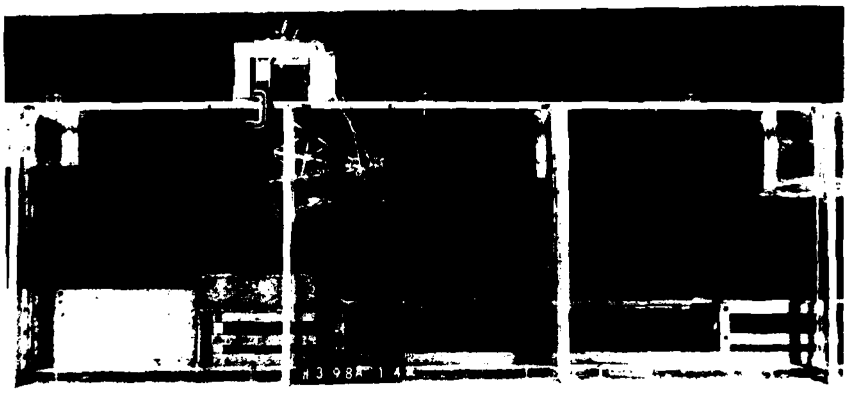


i. Unit discharge = 100.0 cfs/ft; gate opening = 15.0 ft; pool el = 52.0 ft NGVD; and tailwater el = 35.0 ft NGVD

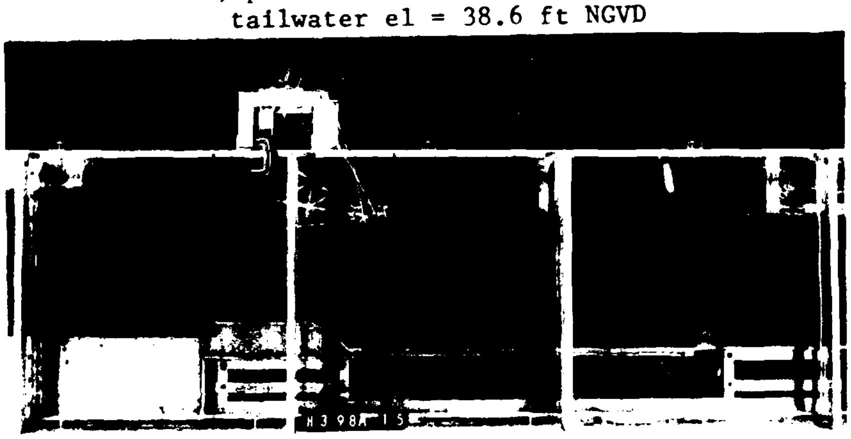
Figure 8. (sheet 3 of 5)



j. Unit discharge = 590.0 cfs/ft; gate opening = 35.0 ft; pool el = 41.9 ft NGVD; and tailwater el = 35.0 ft NGVD



k. Unit discharge = 950.0 cfs/ft; gate opening = 35.0 ft; pool el = 55.0 ft NGVD; and tailwater el = 38.6 ft NGVD



l. Unit discharge = 930.0 cfs/ft; gate opening = 35.0 ft; pool el = 69.1 ft NGVD; and tailwater el = 53.0 ft NGVD

Figure 8. (sheet 4 of 5)

m. Unit discharge = 1370.0 cfs/ft; gate opening = full open; poll el = 52.0 ft NGVD; and tailwater el = 30.0 ft NGVD

Figure 8. (sheet 5 of 5)

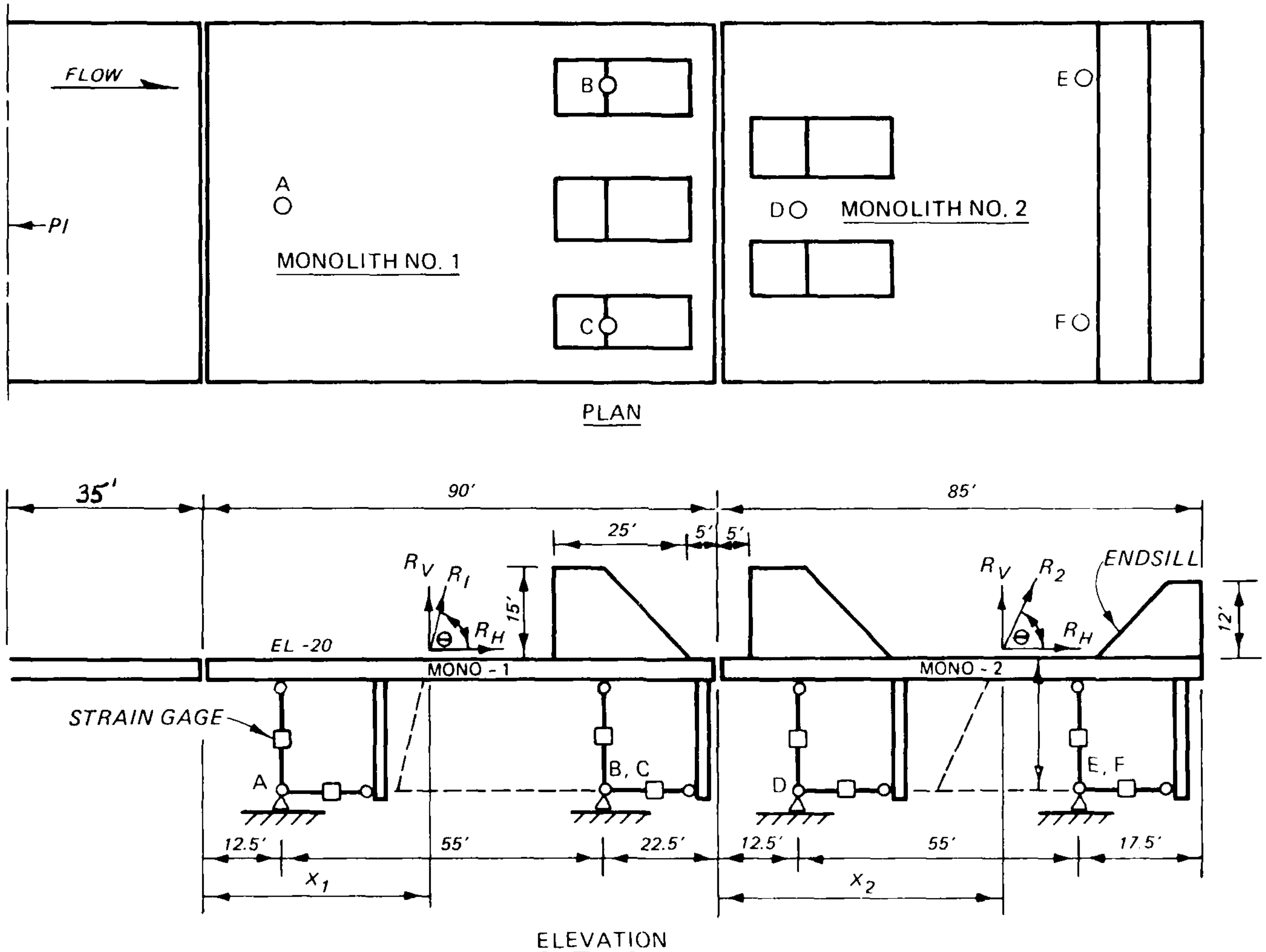


Figure 9. Type 2 monolith design

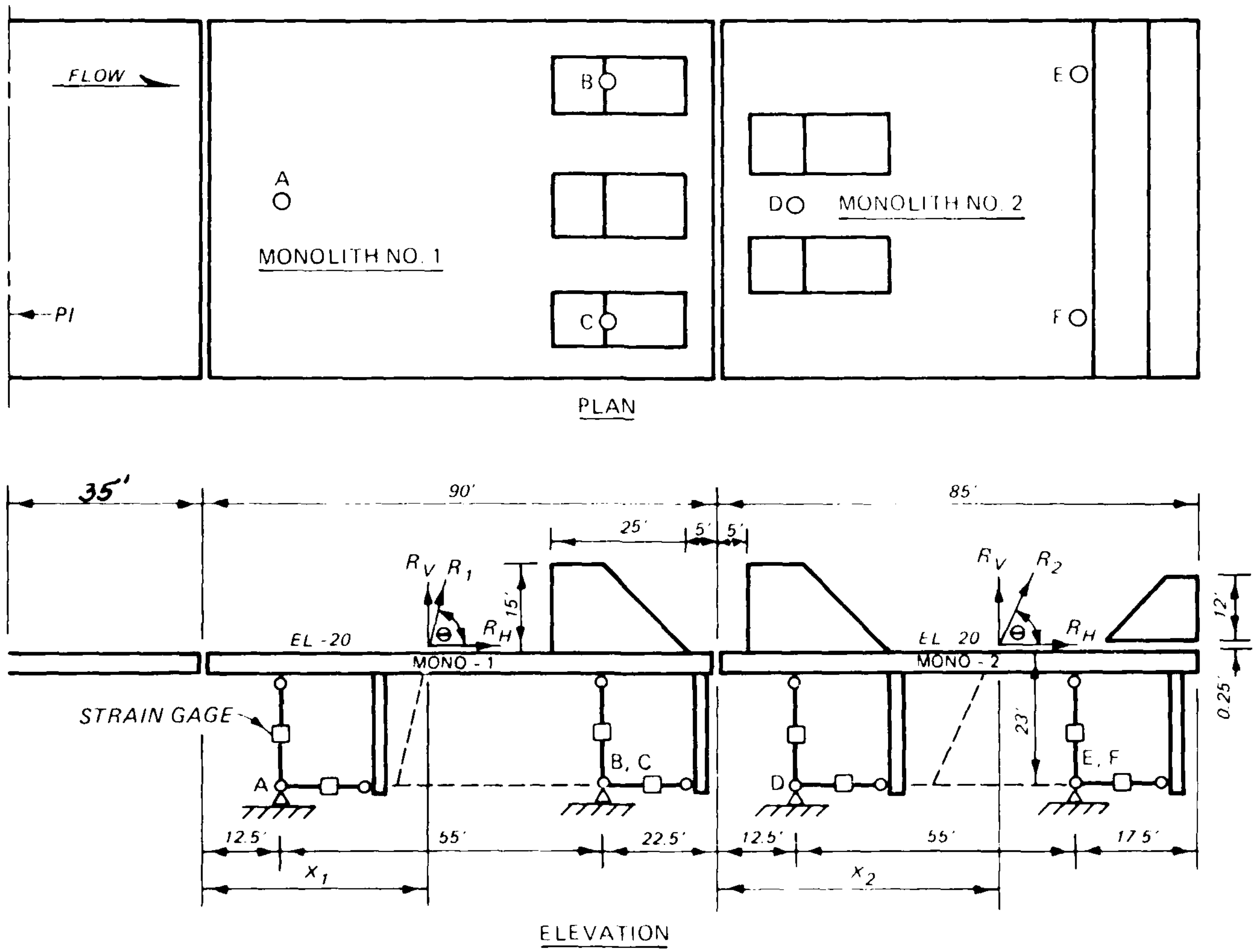


Figure 10. Type 2 monolith design end still detached from monolith No. 2

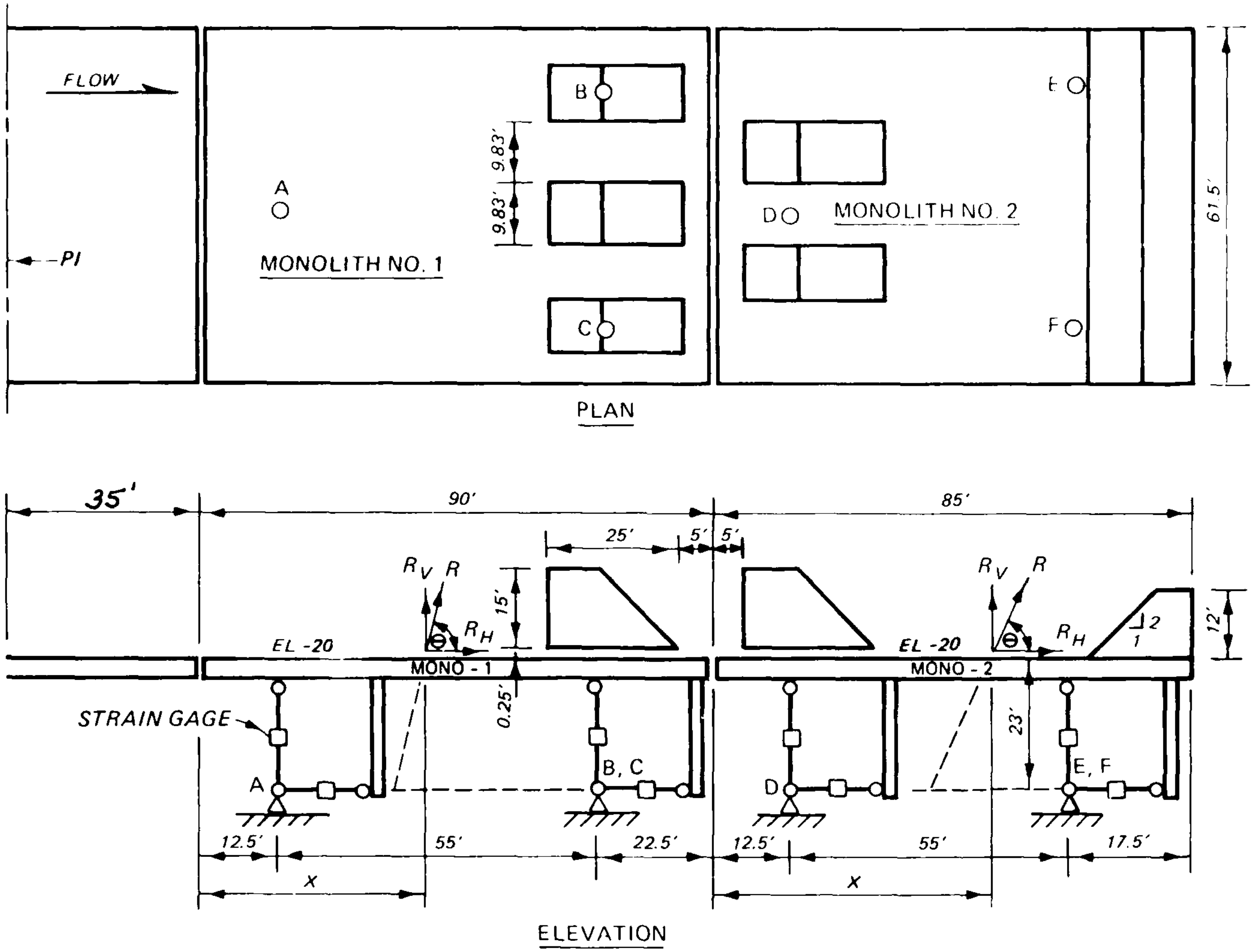


Figure 11. Type 2 monolith design baffles detached from monoliths

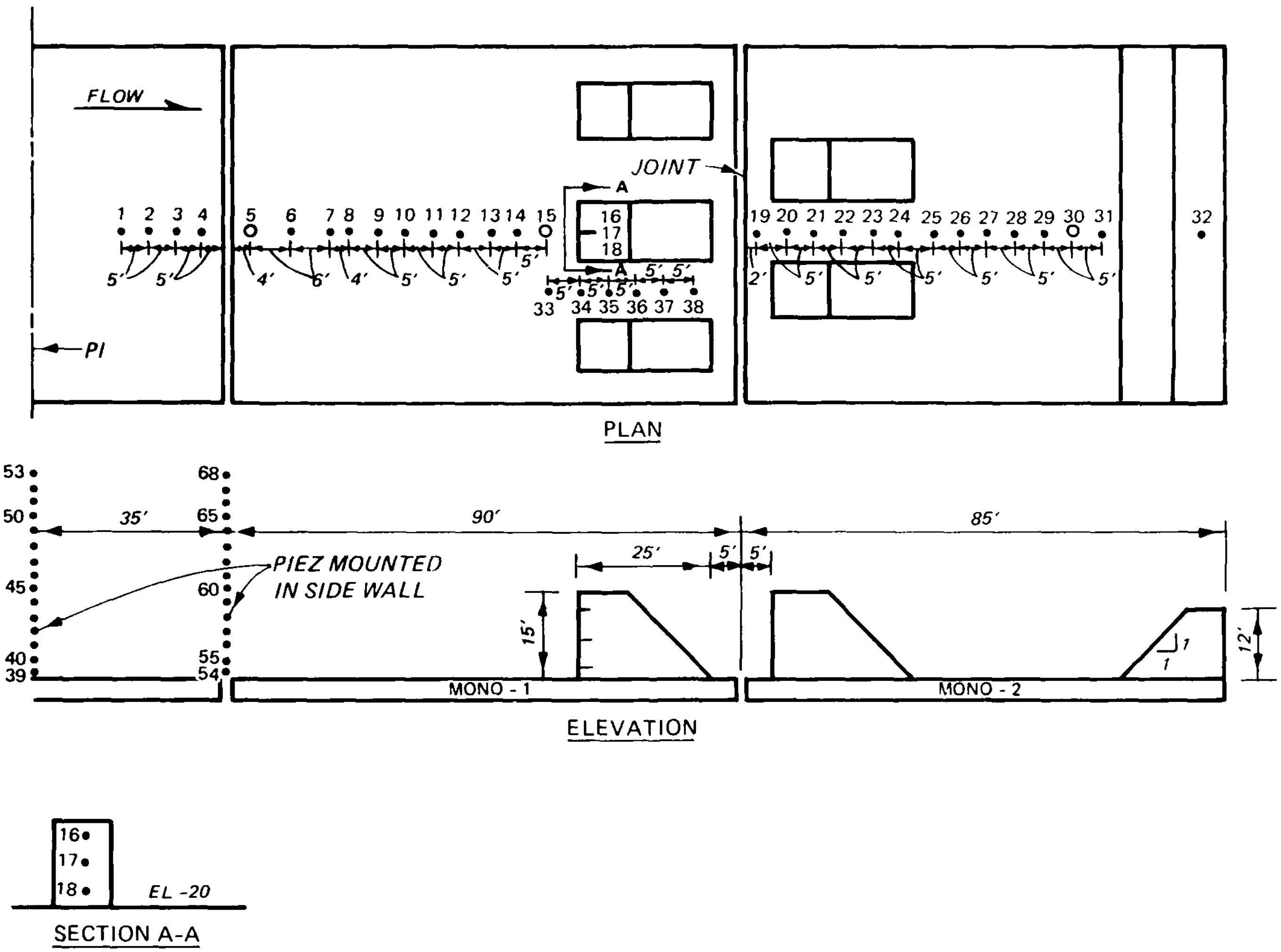


Figure 12. Piezometers and electronic pressure cells

BASIC DATA

●		△		○	
X	ELEV	X	ELEV	X	ELEV
25	44.0	15	27.0	25	17.5
50	46.0	50	27.5	50	16.5
75	46.5	75	32.5	75	22.0
100	46.0	100	32.0	100	22.5
150	46.0	125	33.0	125	24.5
200	47.0	180	35.0	150	25.5
250	47.0	250	35.0	180	26.0
				250	26.0

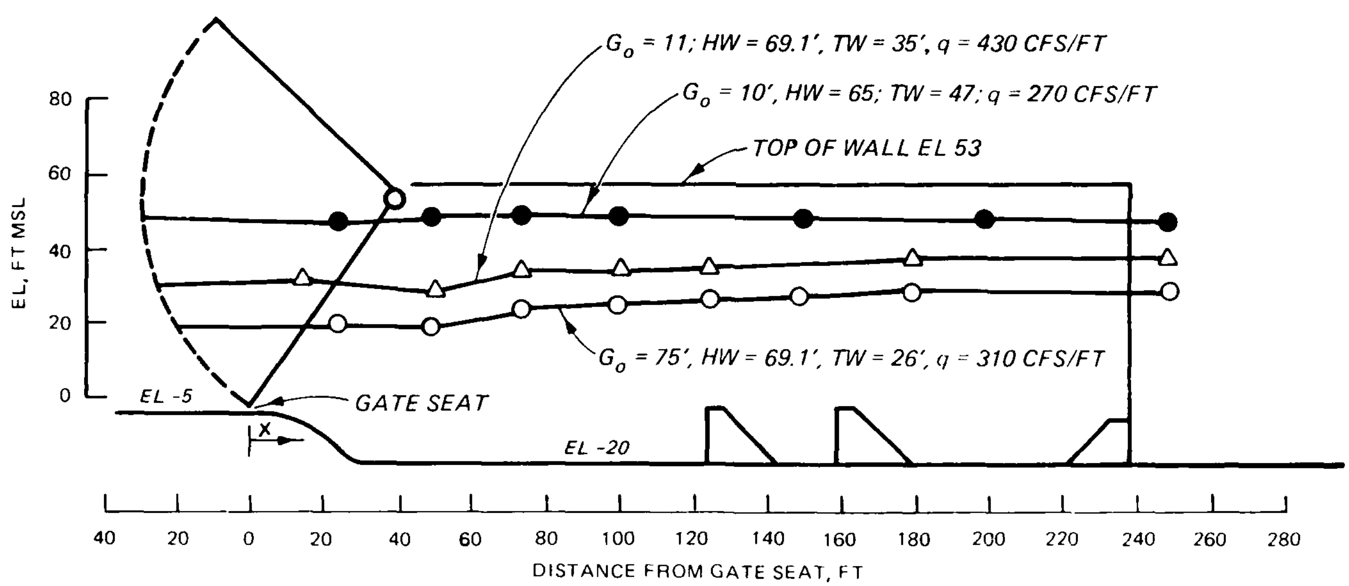


Figure 13. Water-surface profiles (sheet 1 of 3)

BASIC DATA

○		●		□		△		▲	
X	ELEV	X	ELEV	X	ELEV	X	ELEV	X	ELEV
0	60.0	0	43.0	15	34.0	0	32.0	0	32.5
25	60.5	15	43.0	25	37.5	15	32.0	25	9.0
75	61.0	38	47.5	50	37.0	25	33.5	50	14.5
100	61.0	75	45.0	75	36.5	50	35.0	75	20.5
150	60.5	100	45.5	100	37.5	100	37.5	100	28.0
200	61.5	150	45.5	150	37.5	150	41.5	150	32.0
250	61.8	200	46.0	200	39.5	200	38.6	200	30.0
		250	45.9	250	38.3	250	38.6	250	24.3

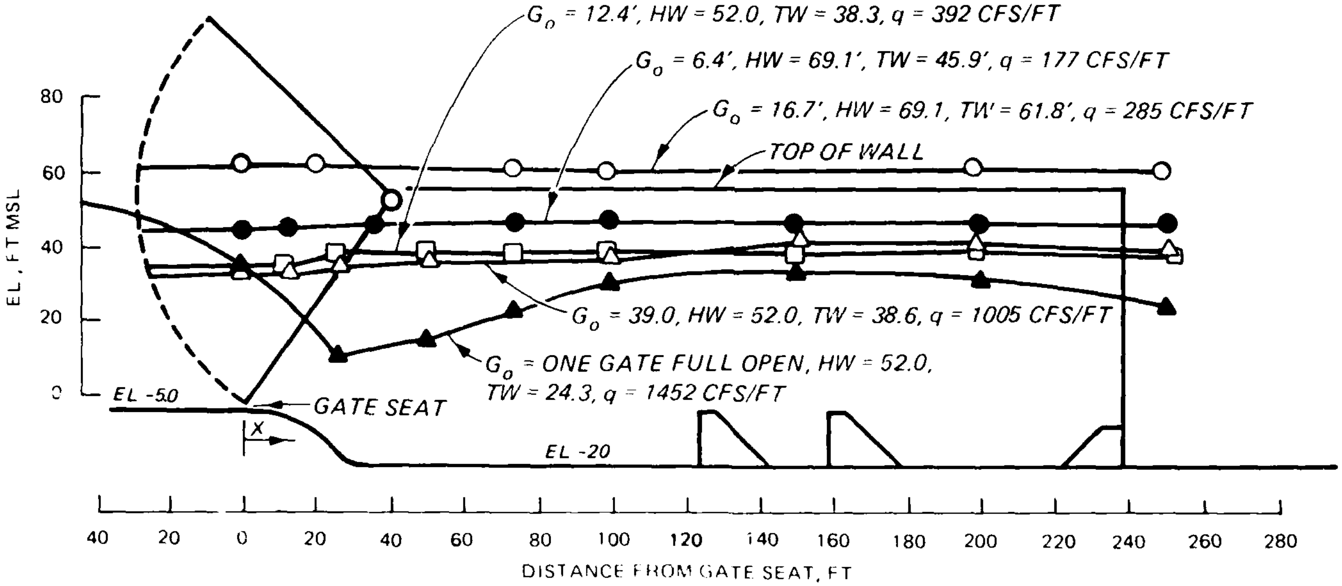


Figure 13. (sheet 2 of 3)

BASIC DATA

○		△		●	
X	ELEV	X	ELEV	X	ELEV
0	47.5	0	33.5	15	29.0
25	48.0	15	33.0	50	31.5
50	48.0	50	34.0	75	33.5
75	49.0	75	37.5	100	34.0
100	50.0	100	40.0	150	35.0
150	52.0	150	43.5	200	36.0
200	54.0	200	40.5	250	35.0
250	53.0	250	39.0		

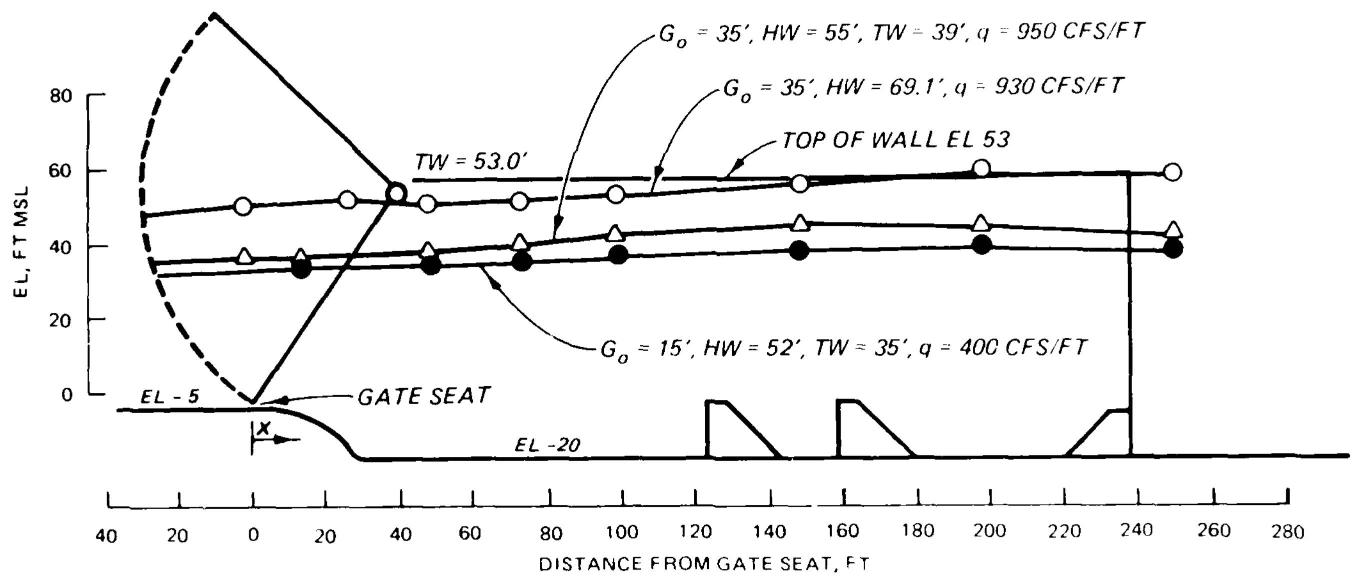


Figure 13. (sheet 3 of 3)

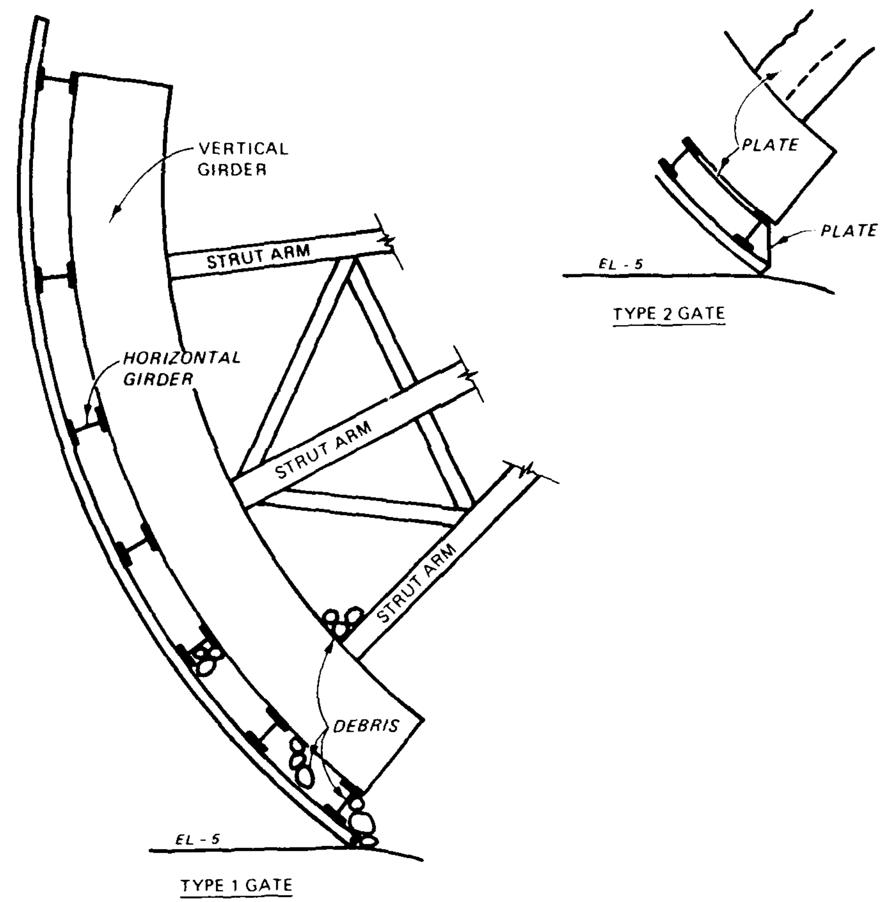


Figure 14. Debris in tainter gate

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